

Engineering, Ethics and Society: The Process of Industrialization

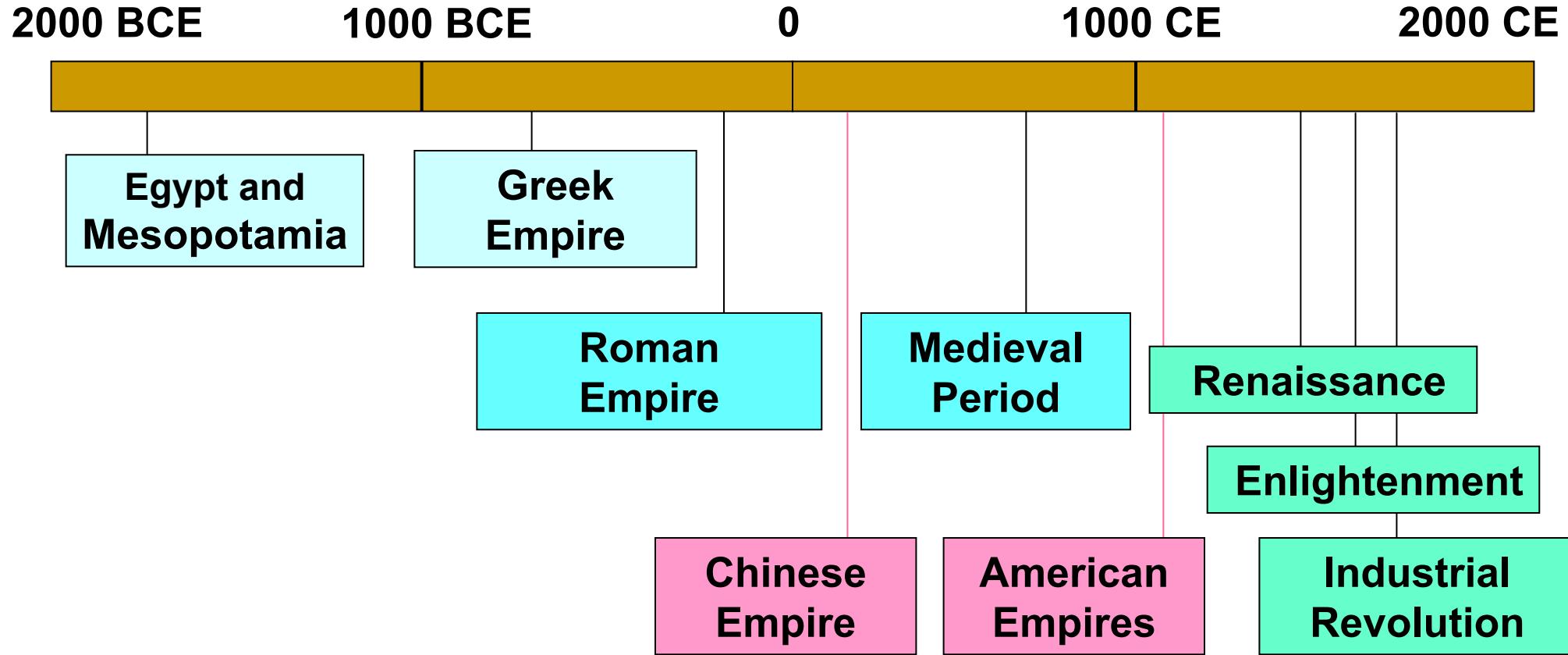
- Log on to UCLA_WIFI
- Go to <https://onlinepoll.ucla.edu>
- Wait for further instructions

Dr. Gershon Weltman
Engineering 183EW, UCLA SEAS
Lecture 6

Lecture Contents

- Egypt & Mesopotamia: Technology Small and Large
- Greek Empire: Instruments and Early Science
- Roman Empire: Template for European Civilization
- Chinese Technology: Starting Ahead of the West
- Medieval Europe: Technology in the “Dark Ages”
- American Empires: Forgotten Civilizations
- The Renaissance: Progress and the Personal Ideal
- The Enlightenment: Separation of Morals and Science
- The Industrial Revolution: Products of Science and Technology
- Reactions: Societal & Individual

Broad Historical Timeline



Technology evolves in terms of complication, adaptation, specialization, persistence and – less frequently than we might think – *becomes extinct*.

Technology of Egypt and Mesopotamia

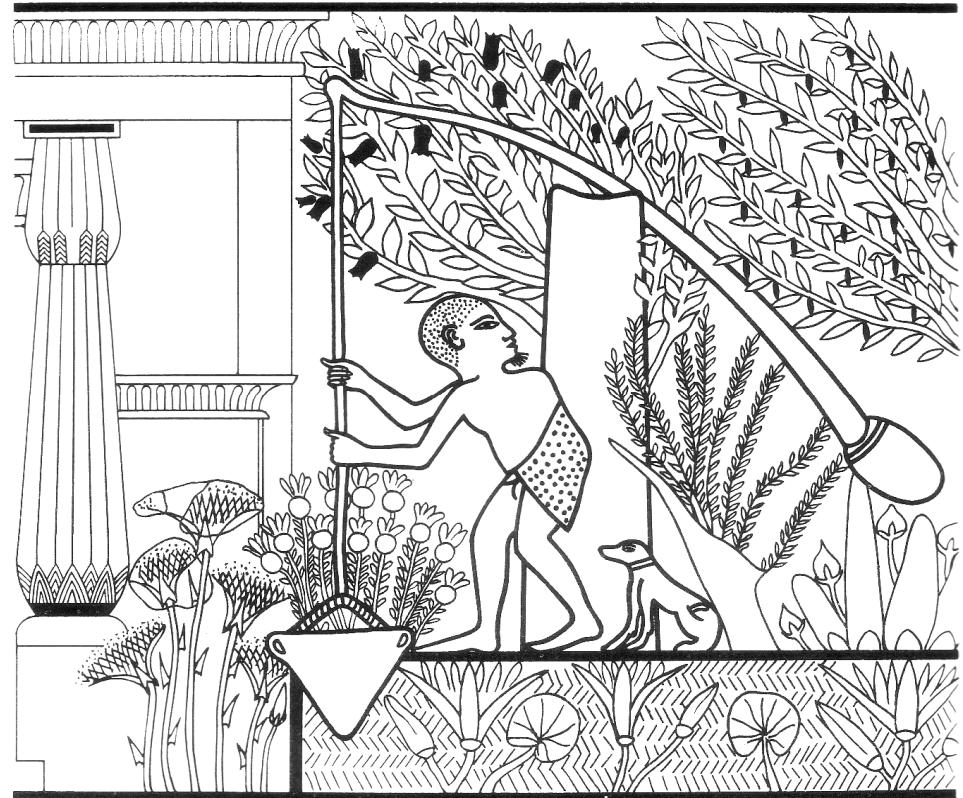
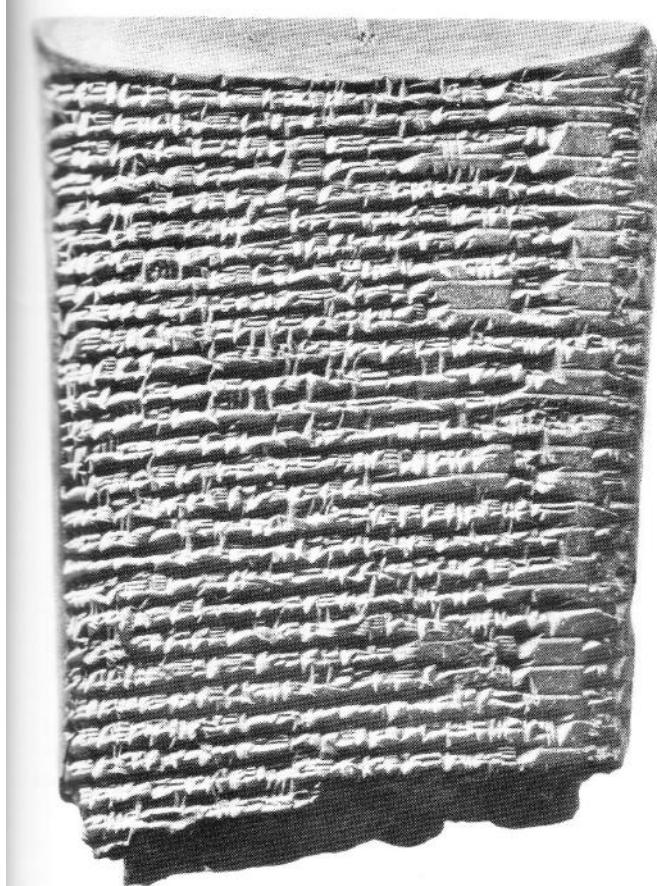
- Animals; Power, Food and Clothing
- Agriculture; Family and Communal
- Cloth; Spinning and Weaving
- Metals and Iron; Weapons, Tools and Utensils
- Pottery; Spinning and Glazing
- Glass; Ornamental and Functional
- Structures; Wood, Brick and Stone
- Wheels; Transport and Warfare
- Water Conduits; Irrigation, Drinking and Sewage
- Writing, Pictures and Models; Communication; Record Keeping; Religious Practice

“Agriculture was the basis of the economy, home was the center of most production and the main source of power was man or beast.”

A.G. Drachmann

Technology on a Small Scale.....

Cuneiform Tablet
Babylonia, 650 BC



Watering a Garden, Egypt 1300 BC

....and on an Immense Scale



Pyramids of Giza, Egypt, 2500 BC

Philea Temple, Egypt, 300 BC

Building the Pyramids: Geometry + Sweat

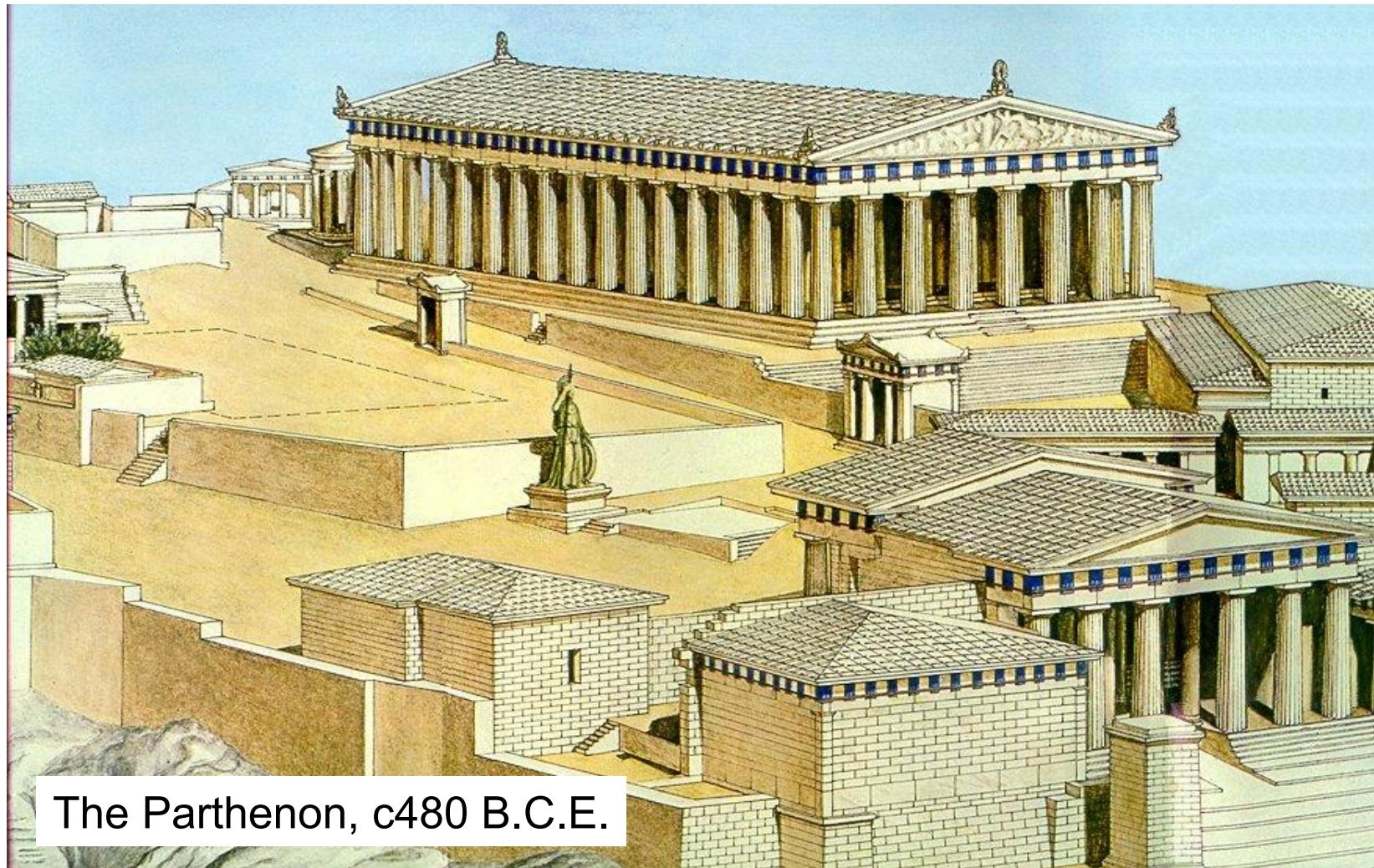


Photograph of pyramid model at Boston Museum of Science

A Recent Suggestion



Greek Architecture: Classical Aesthetics



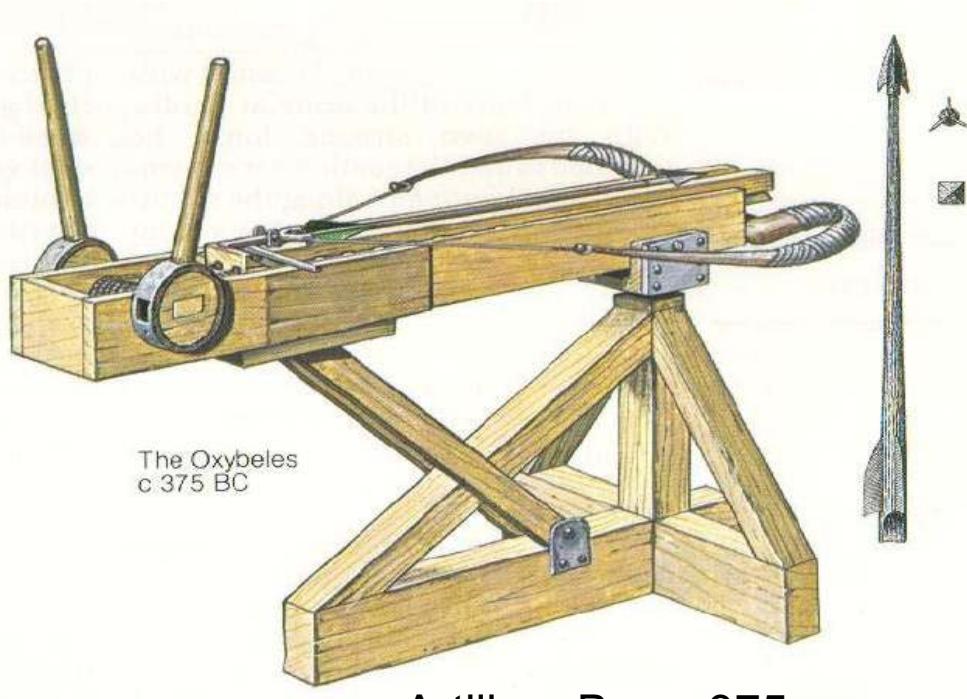
The Parthenon, c480 B.C.E.

Classical Aesthetics at the Time



Brightly colored statues, approximately 500 B.C.

Greek Mechanisms & Instruments



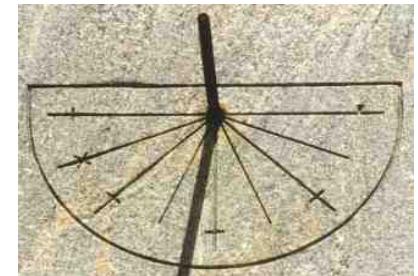
Artillery Bow c375 BC

A surprising amount of science and precision, but the mechanisms were used more for academic study and demonstration than for civil engineering or warfare

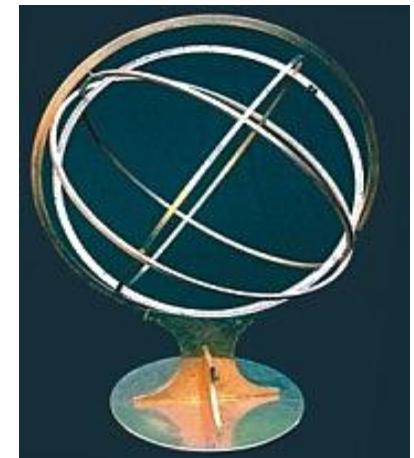
Surveying Instrument
c100BC



Astrological Gnomon
c100 BC



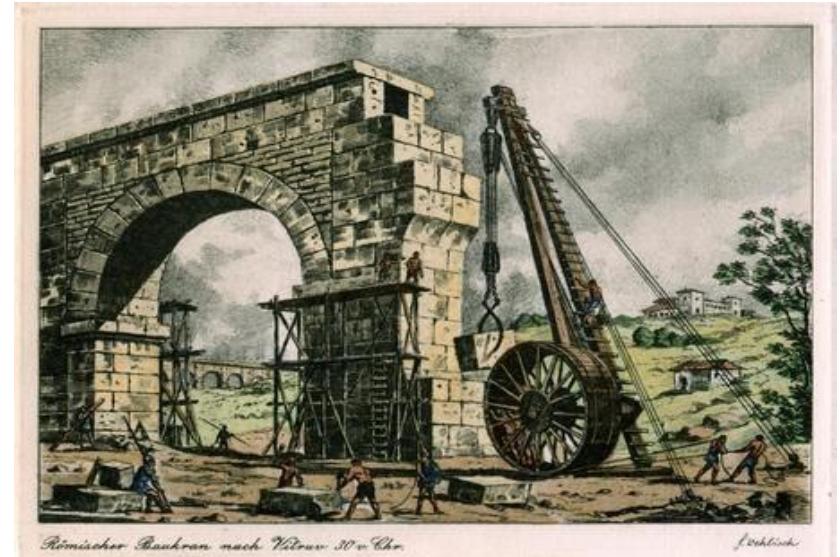
Astrolabe
c200 AD



Roman Engineering

- Concrete Arches, Vaults & Domes
- Power Transmission
 - Gearing
 - Screws and Screw Drives
- Long Distance Aqueducts
- Permanent Roads
- Ship Building and Shipping
- Military Technology:
 - Cross Bow
 - Catapult
 - Command and Control
- City Planning

Romans used their relatively straightforward and practical technologies for civil engineering, home products, transportation and warfare



Building for Sport and Entertainment....

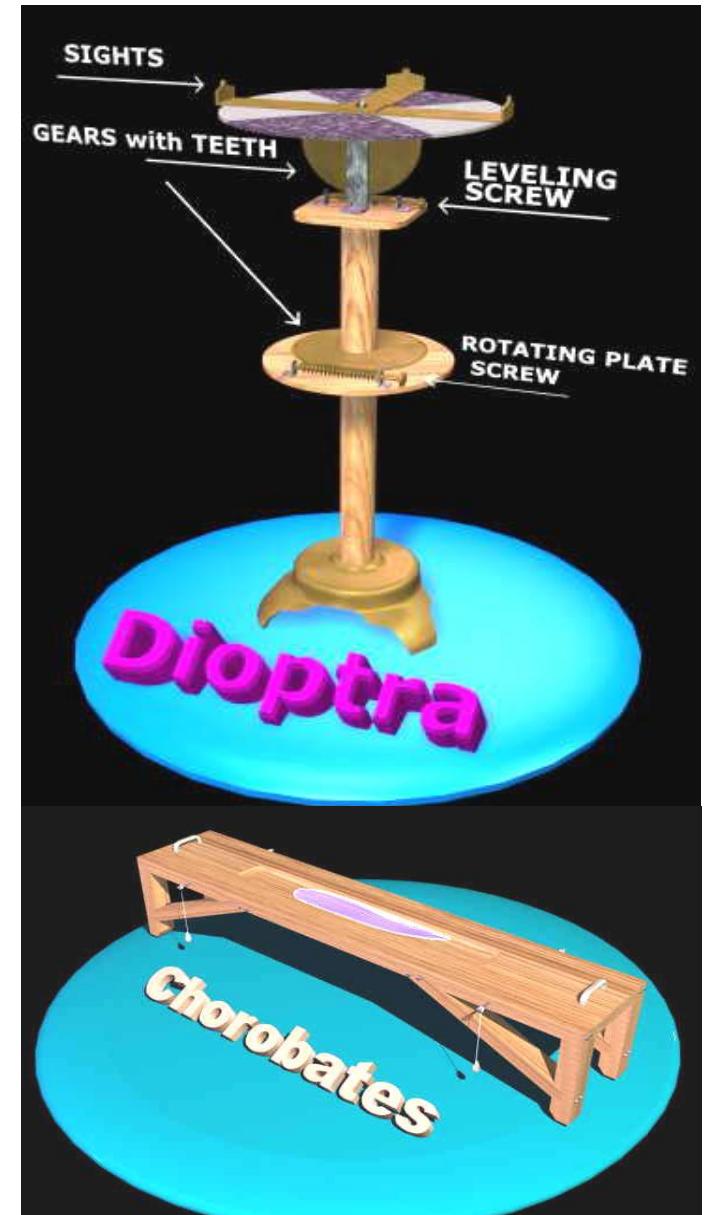
The Coliseum in Rome, 70 AD, Photo Restored



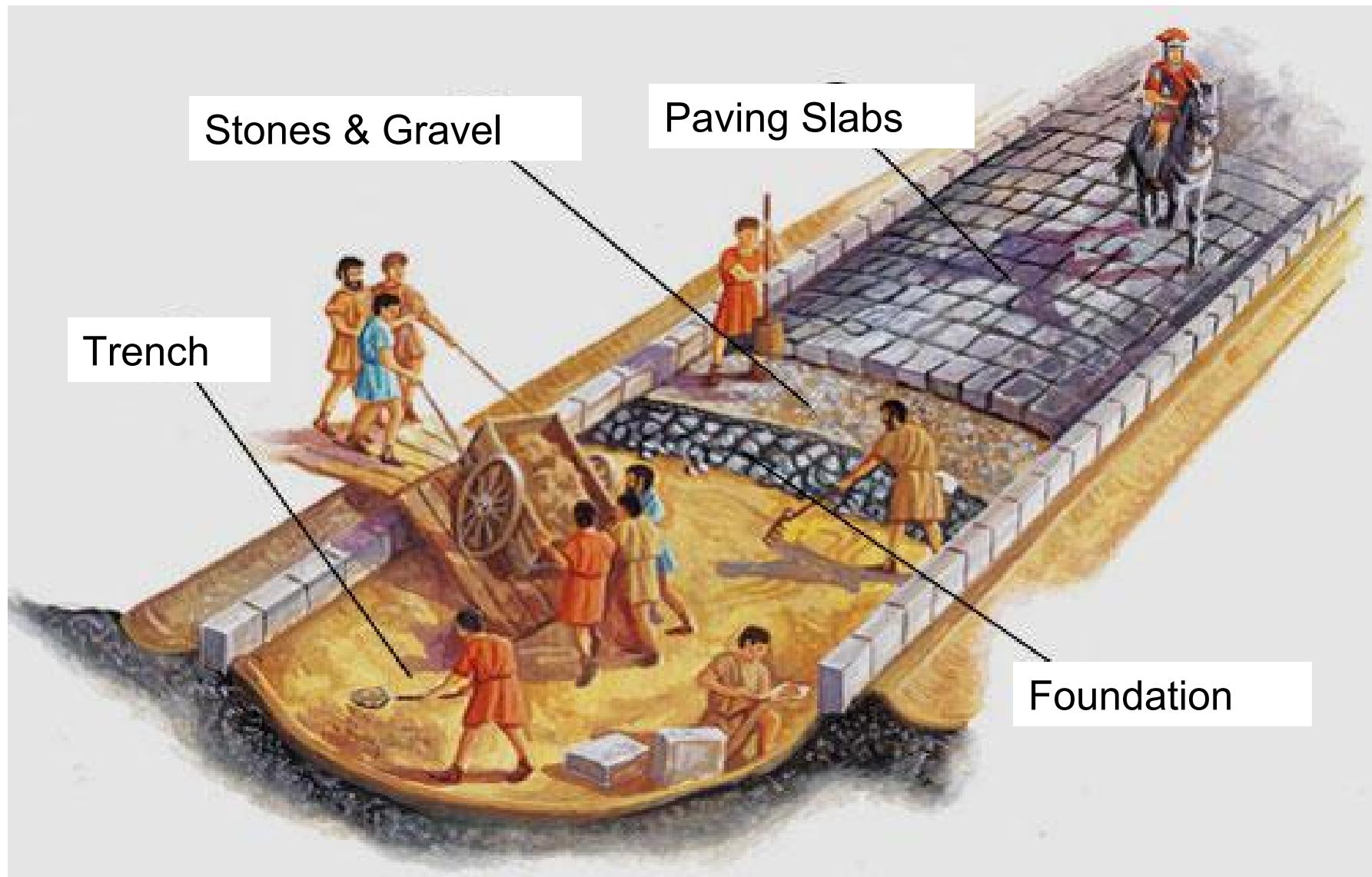
....for Water Delivery....



Roman Aqueduct



....and for Land Travel



The Roman Empire: “All Road Lead to Rome”



<http://www.utexas.edu/courses/ancientfilm>

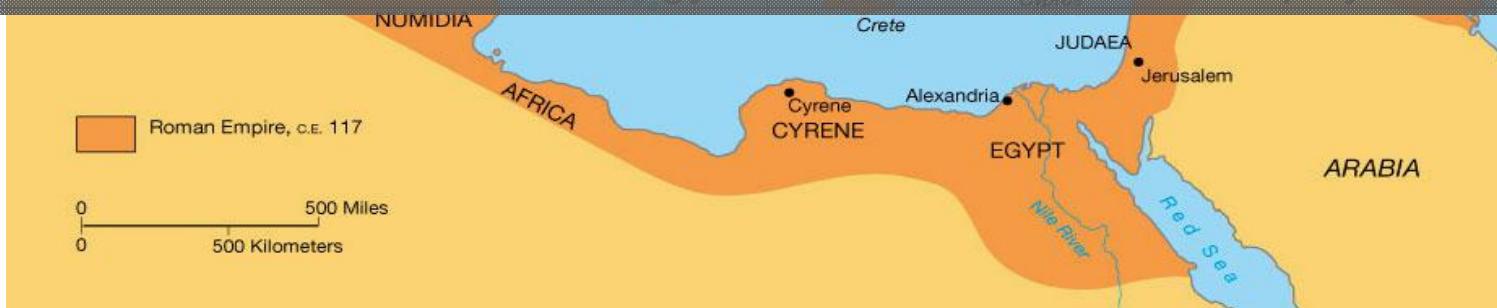
The Roman Empire: “All Road Lead to Rome”



“The Romans are known to history as great engineers.
Partly this is due to the monumentality of their construction...
(but) partly too it is owing to their organizational abilities.
It is perhaps in this last category that the Romans truly excelled.”

A.G. Drachman

‘The Mechanical Technology of Greek and Roman Antiquity,’ 1963



<http://www.utexas.edu/courses/ancientfilm>

Roman Organization: The European Template



Roman Organization: The European Template

- Standardized Cities
 - Consistency: Throughout the Roman Empire
 - Infrastructure: Housing, public buildings, commerce, entertainment, education, water distribution, sewage disposal,
 - Governance: Laws, courts and security,
- Integrated State
 - Politics and Military: Centrally coordinated, widely applied
 - Transportation: Goods moved by land and sea
 - Communication: Over road networks and by signals
 - Coinage: Roman money accepted internationally
 - Social Stratification: Politicians, lawyers, doctors, engineers, soldiers, artisans, landowners, tradesmen and slaves
 - Common Culture: Both *coercive and voluntary* dispersion



Roman Classical



The Pantheon, Rome, ~126 CE

Classical Architecture in Our Environment



United States Supreme Court
Washington DC



City Courthouse
New York, NY

Greece and Rome provided the early architectural and artistic ideals for the Western World

Roman Technology for Daily Life....



Temple of Apollo Pompeii,
c. 79 CE Current Ruins

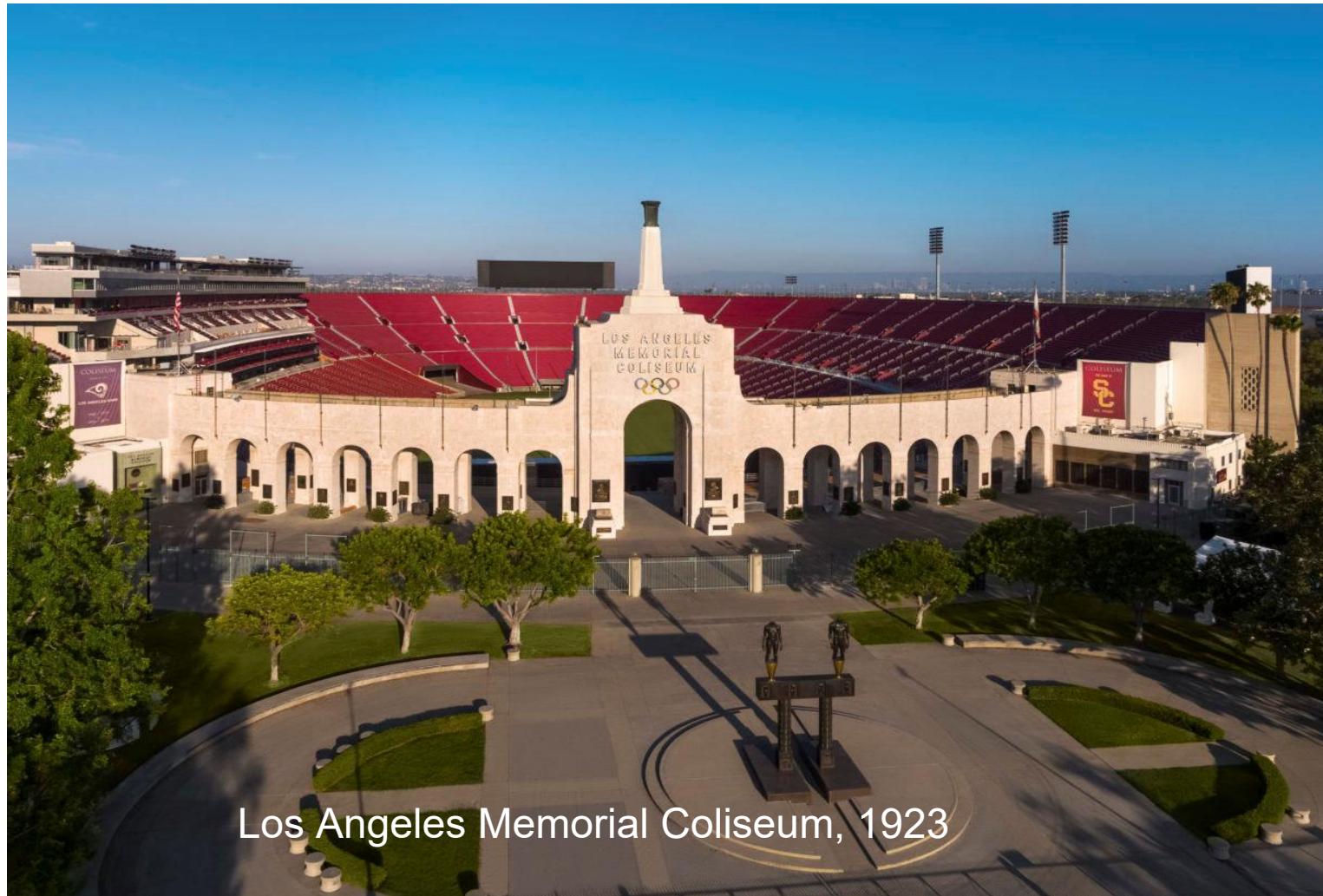
Temple of Apollo
Photo Restored

...Reflected in Life Today...



Los Angeles, California, The Grove, c. 2000

...And Of Course



Los Angeles Memorial Coliseum, 1923

Chinese Technology: 2000 BCE to 1000 CE



4000 year old noodles
excavated in northwestern
China, Nature 10/13/05

■ Agriculture

- Seed Drill (~2000 BC)
- Row Cultivation and Intensive Hoeing (~2000 BC)
- Chain Pump for Irrigation (~100 CE)

■ Construction

- Suspension Bridge (~100 CE)
- The Great Wall of China (~700 BC to 1500 CE)

■ Materials and Processes

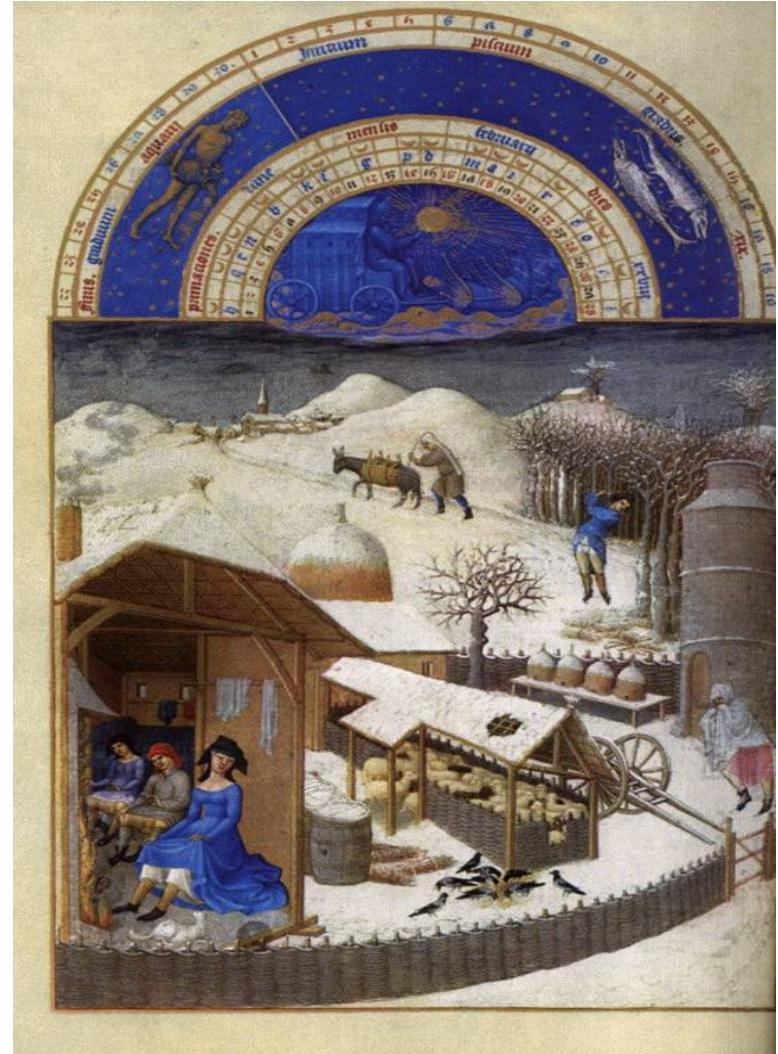
- ✓ Paper for Clothing, Armor and Writing (~200 CE)
- ✓ Blast Furnace and Steel (~300 CE)
- ✓ Printing with Movable Type (~600 CE)
- ✓ Gunpowder and Rocketry (~850 CE)
- ✓ Compass and Navigation (~1000 CE)
- ✓ Horse Stirrups (~600 CE)

Many of these great innovations did not appear in Europe until the very late Medieval Period or the early Industrial Revolution. Why?

Europe's Not-So-Dark Ages (500-1450 CE)

Medieval Society:

- Church Centered
- Feudal Social Structure
- Enhanced Roman Technology
 - Asian & Arabian Influences
 - Agricultural Surpluses
 - Emerging Capitalism
 - Great Civic Cathedrals
 - Beginning of “Invention”



Medieval Technology: Improved Agriculture

500 750 1000 1250 1500

Heavy Plow



Image from Medievalists.net

Medieval Technology: Improved Horse Power

500 750 1000 1250 1500

Heavy Plow

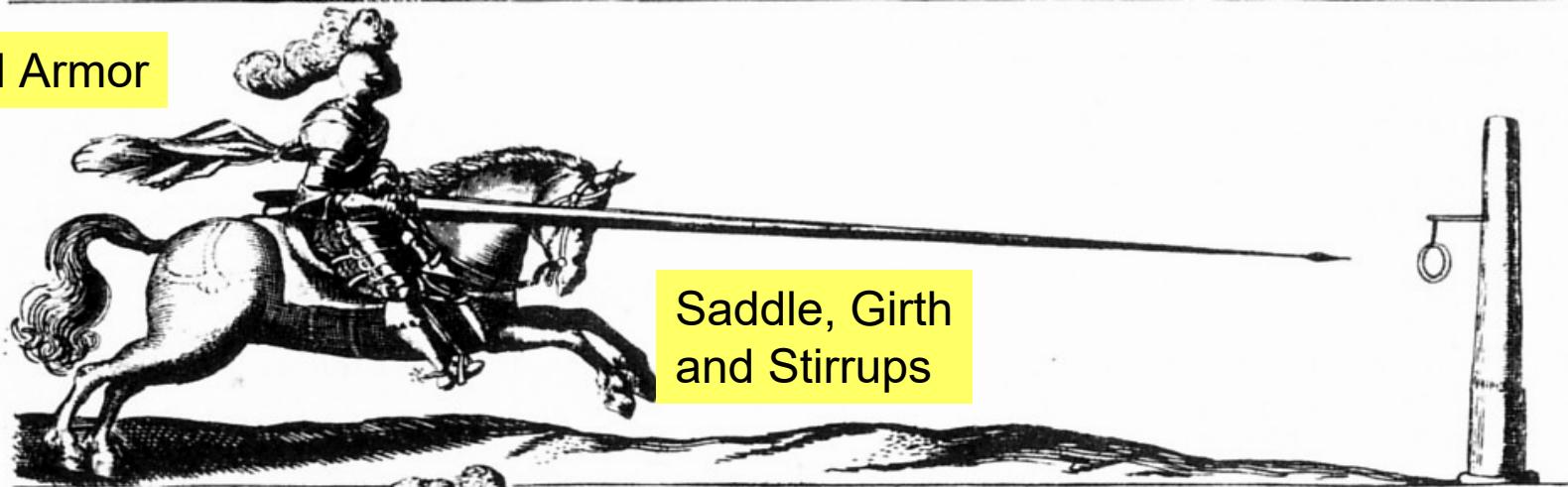
- Horse Power
- Horse Shoes
 - Breast Strap
 - Horse Collar
 - Stirrup



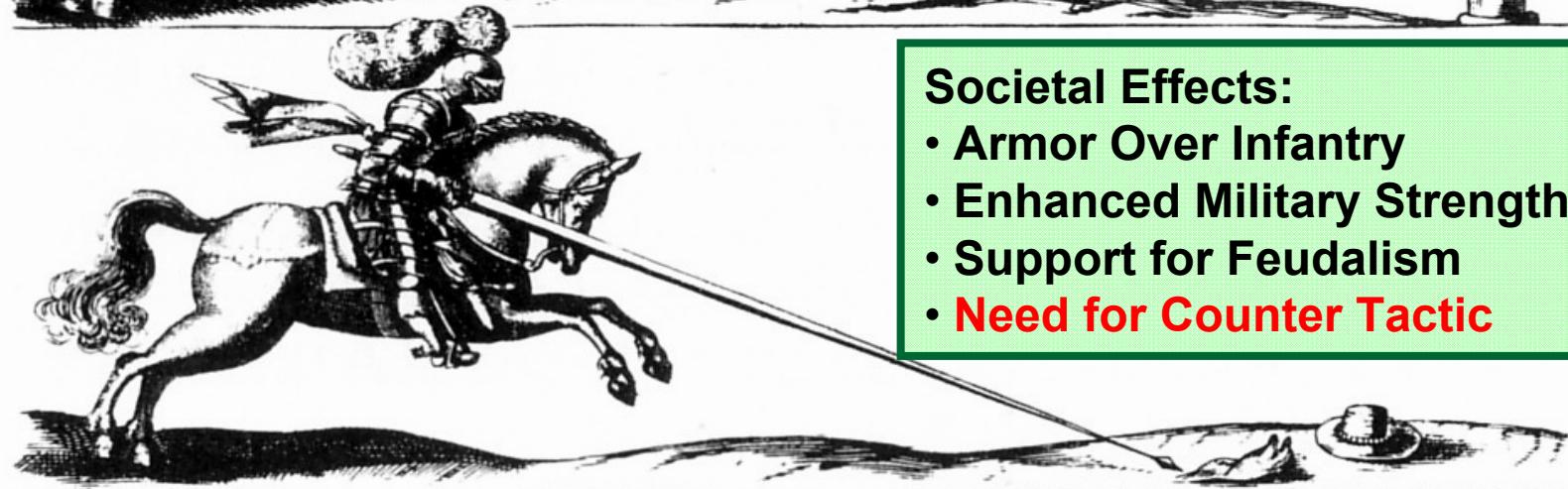
Basil I the Macedonian and his son (~880 CE)

Influence of Technology: The Mounted Knight

Metal Armor



Saddle, Girth
and Stirrups



Societal Effects:

- Armor Over Infantry
- Enhanced Military Strength
- Support for Feudalism
- Need for Counter Tactic

Technology & Society Shifts: The Anti-Knight

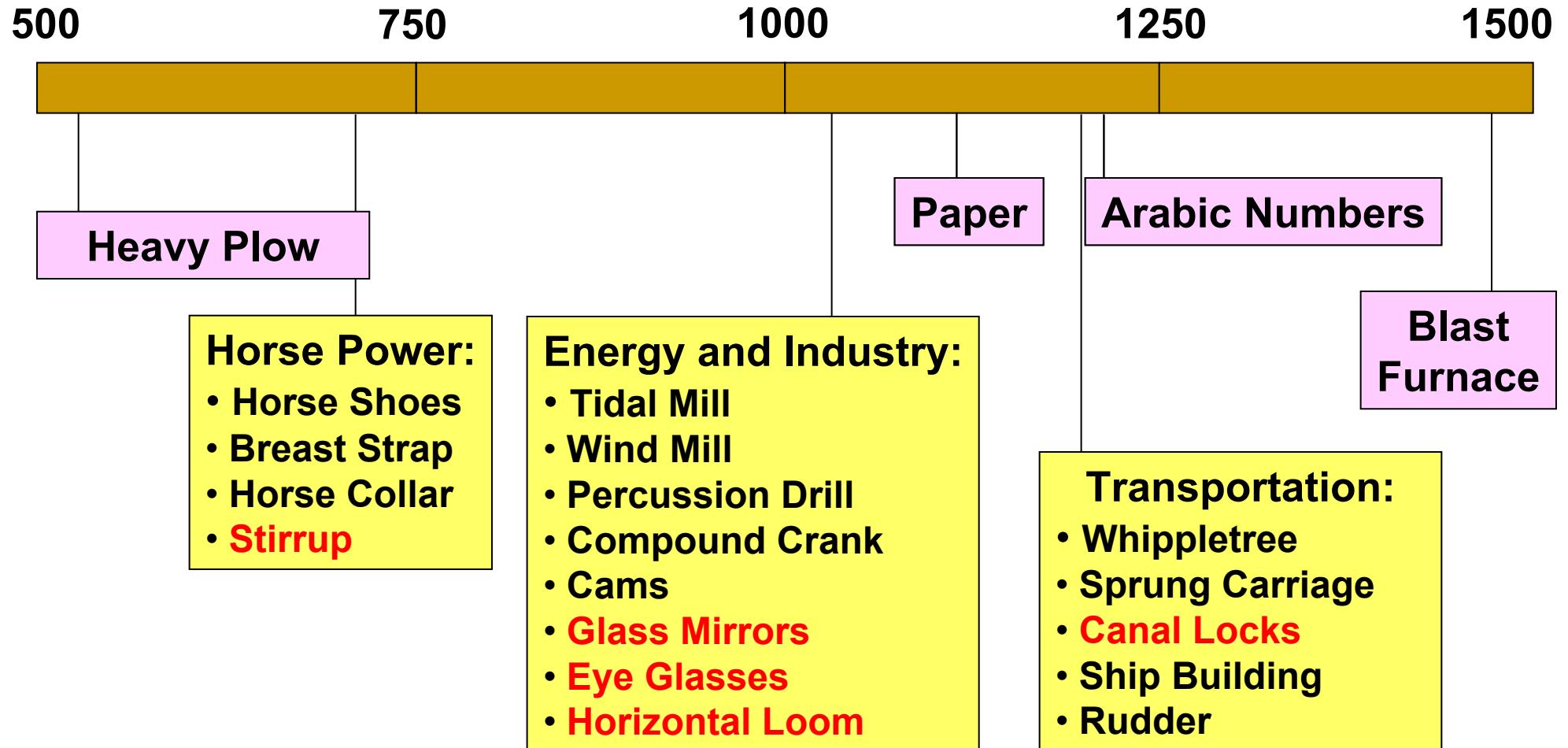


- Armor piercing capability
- 1000 arrows/second volleys
- First fielded 1000 to 1300
- Decisive at Agincourt (1415) in English defeat of French army
- All able-bodied Englishmen armed and trained
- Power shifted to Yeomanry
- Supplanted in turn by firearms



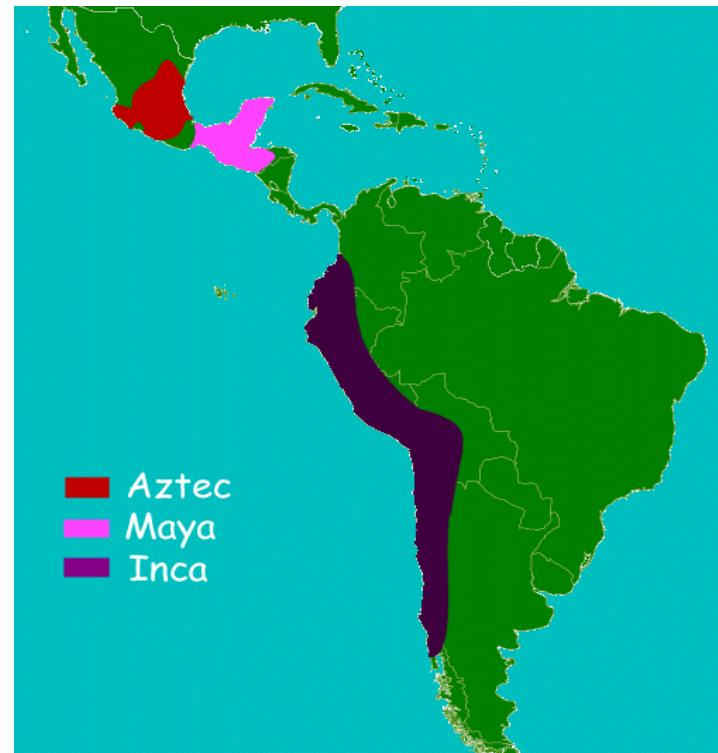
Image from <http://www.history-magazine.com/longbow.html>

Late Medieval: Industrial Prerequisites



Meanwhile in the Americas (900–1500 C.E.)

- Aztecs, Mayas and Incas
 - Empires and city states
 - Social strata and cooperative work
 - Religious rituals and games



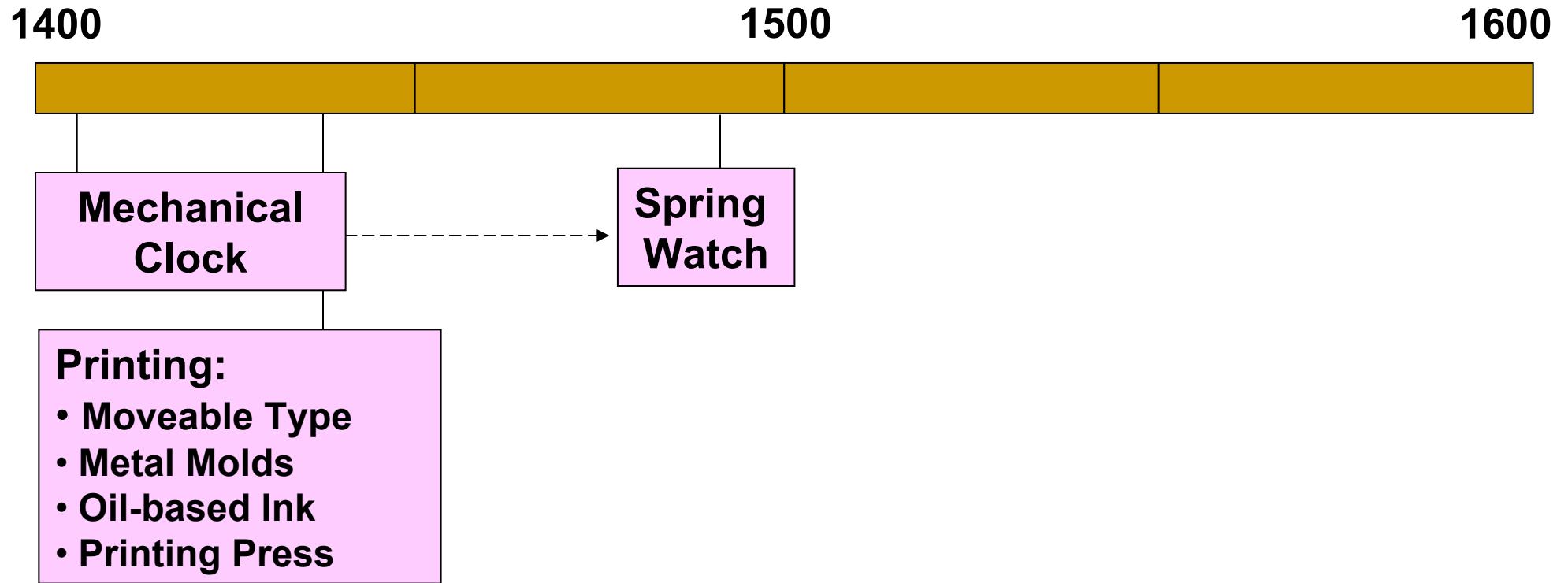
In the Americas (900–1500)

- Aztecs, Mayas and Incas
 - Empires and city states
 - Social strata and cooperative work
 - Religious rituals and games
- Science and Technology
 - Astronomy, mathematics and calendars
 - Cities, roads and monuments
 - Agricultural terracing and irrigation
 - Writing, painting and models
- Transfers to Europe
 - ✓ Agriculture: Corn, tomato, potato, coffee, chocolate, avocado, etc., etc.
 - ✓ Treasure; Gold and silver

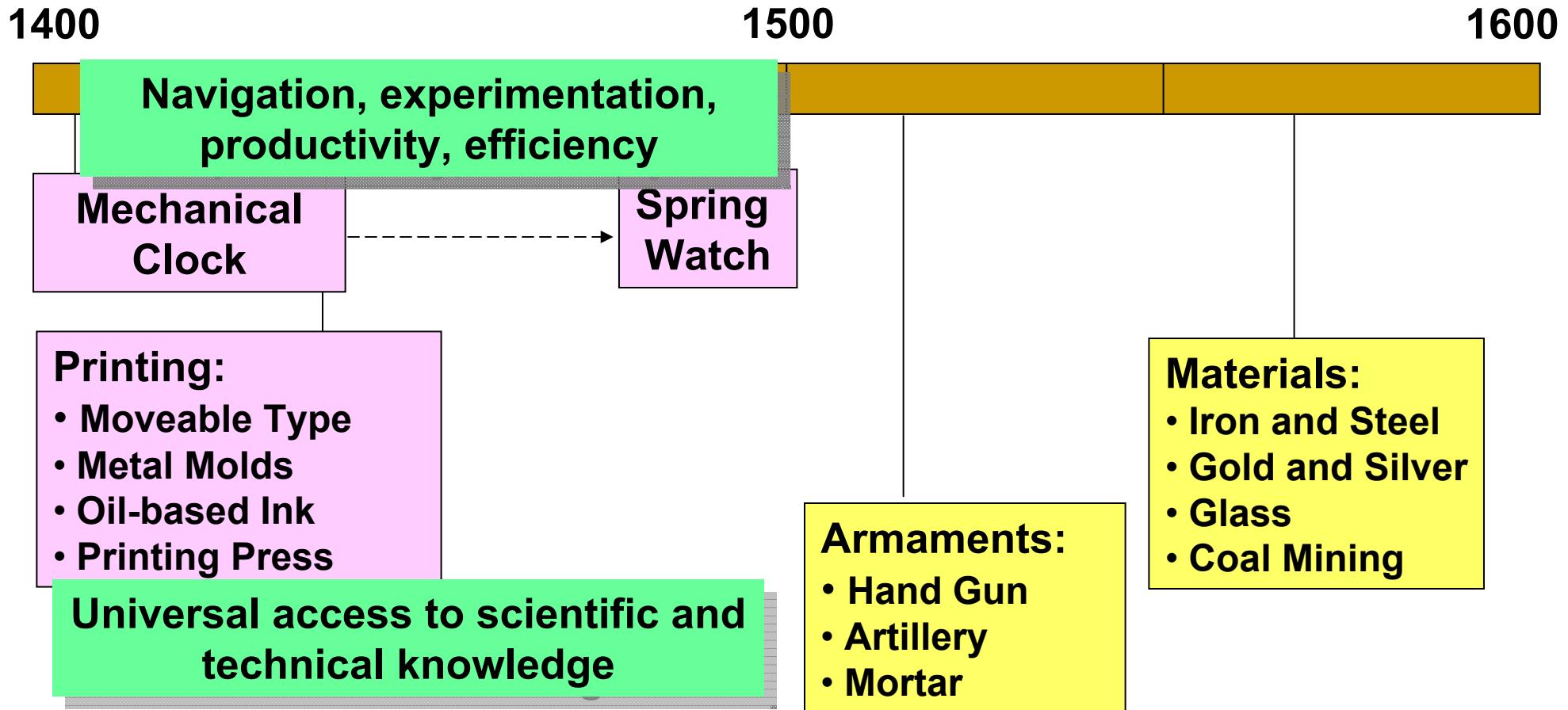
The extensive Mayan, Aztec and Inca empires were destroyed by Spanish conquest and disease, leaving us with less memory and history than they deserve.



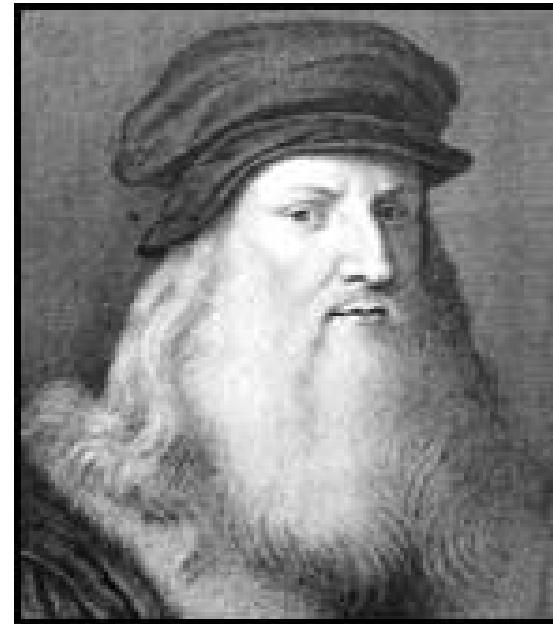
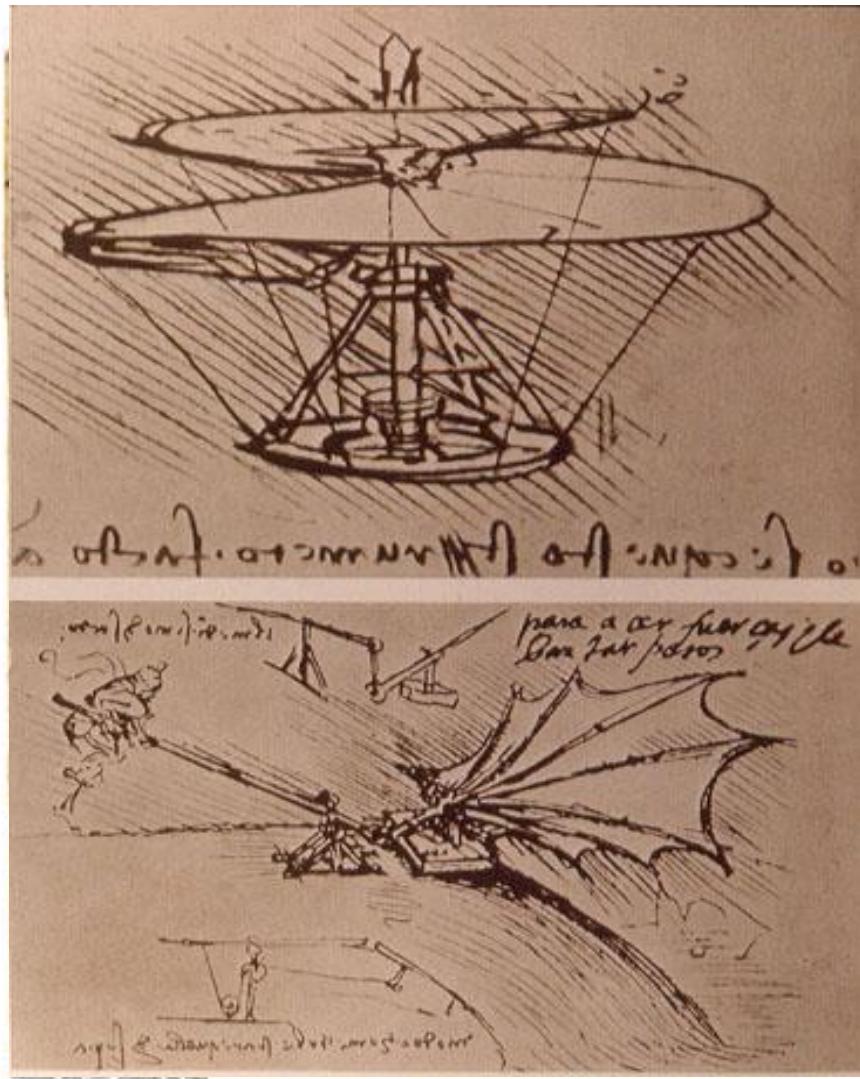
The Renaissance: Industrial Basics & Societal Effects



The Renaissance: Industrial Basics & Societal Effects



Leonardo da Vinci: Renaissance Man

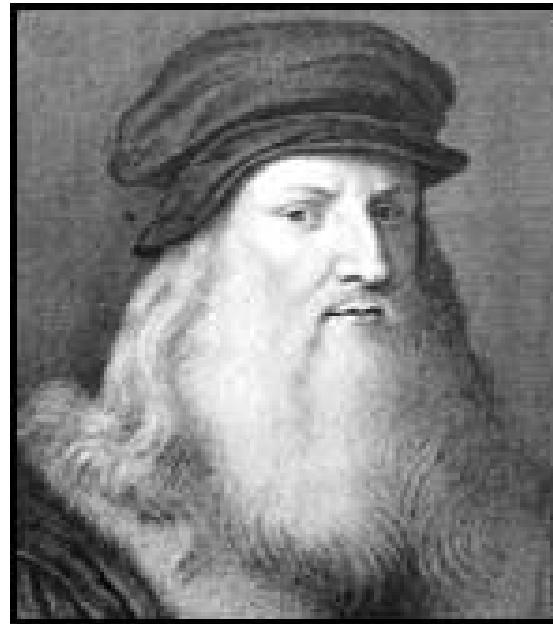


1452–1519

- Painter
- Sculptor
- Architect
- Engineer
- Scientist

Leonardo de Vinci: Renaissance Man

- The Renaissance Ideal
 - Individualism
 - Versatility
 - Science, Technology and Art
 - Publication and Discussion



1452–1519

- Painter
- Sculptor
- Architect
- Engineer
- Scientist

The Enlightenment: Separating Morals & Science

1800

**God's Words
& God's Works**

Deism & Nature's God

- Nature's laws are public, they are not private and inscrutable;
- Belief in laws is a matter of evidence, not of choice or opinion;
- People in nature are free and equal;
- Government is by agreement among people, not by divine law.

1600

Rene Descartes
Francis Bacon

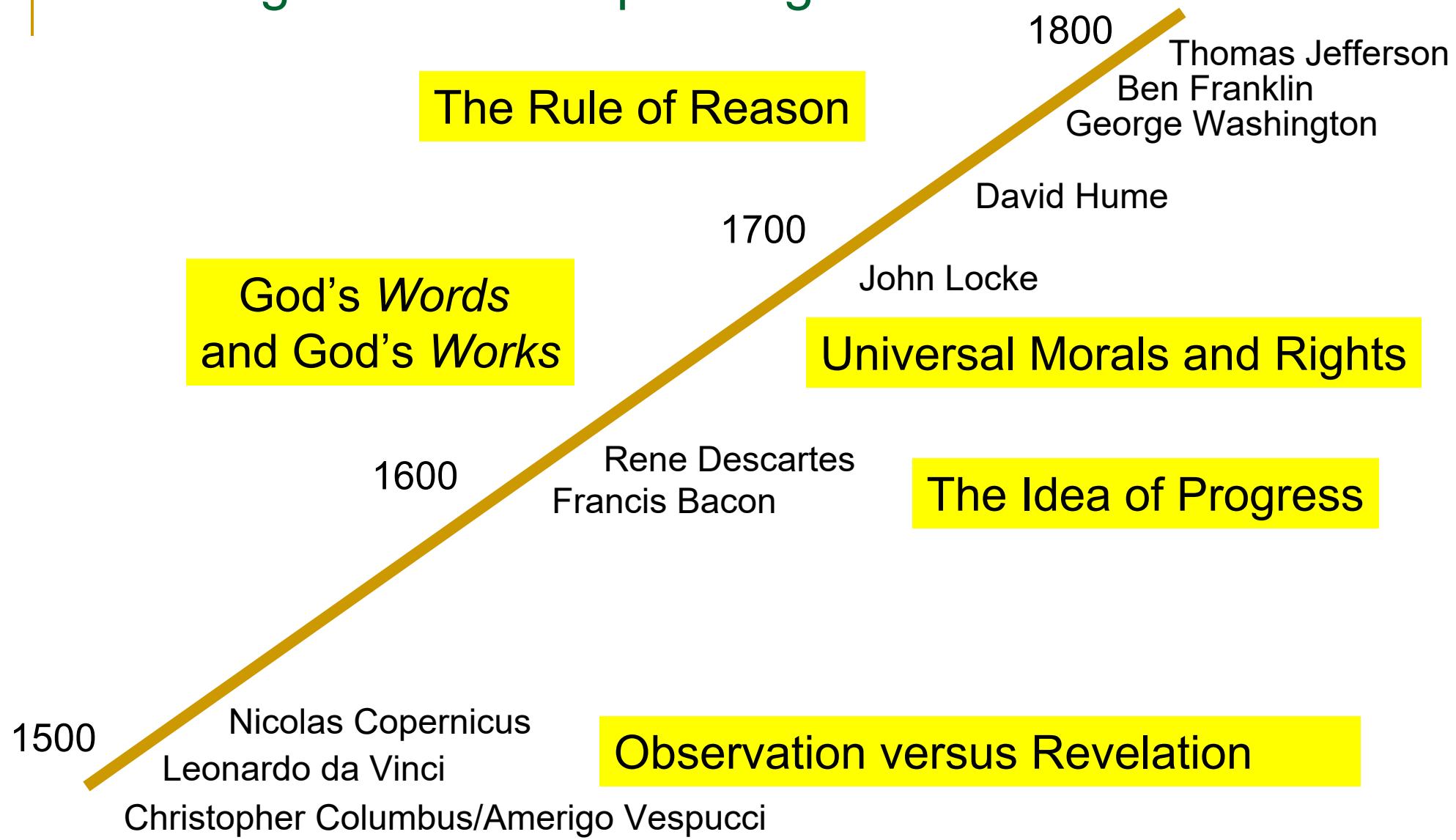
The Idea of Progress

1500

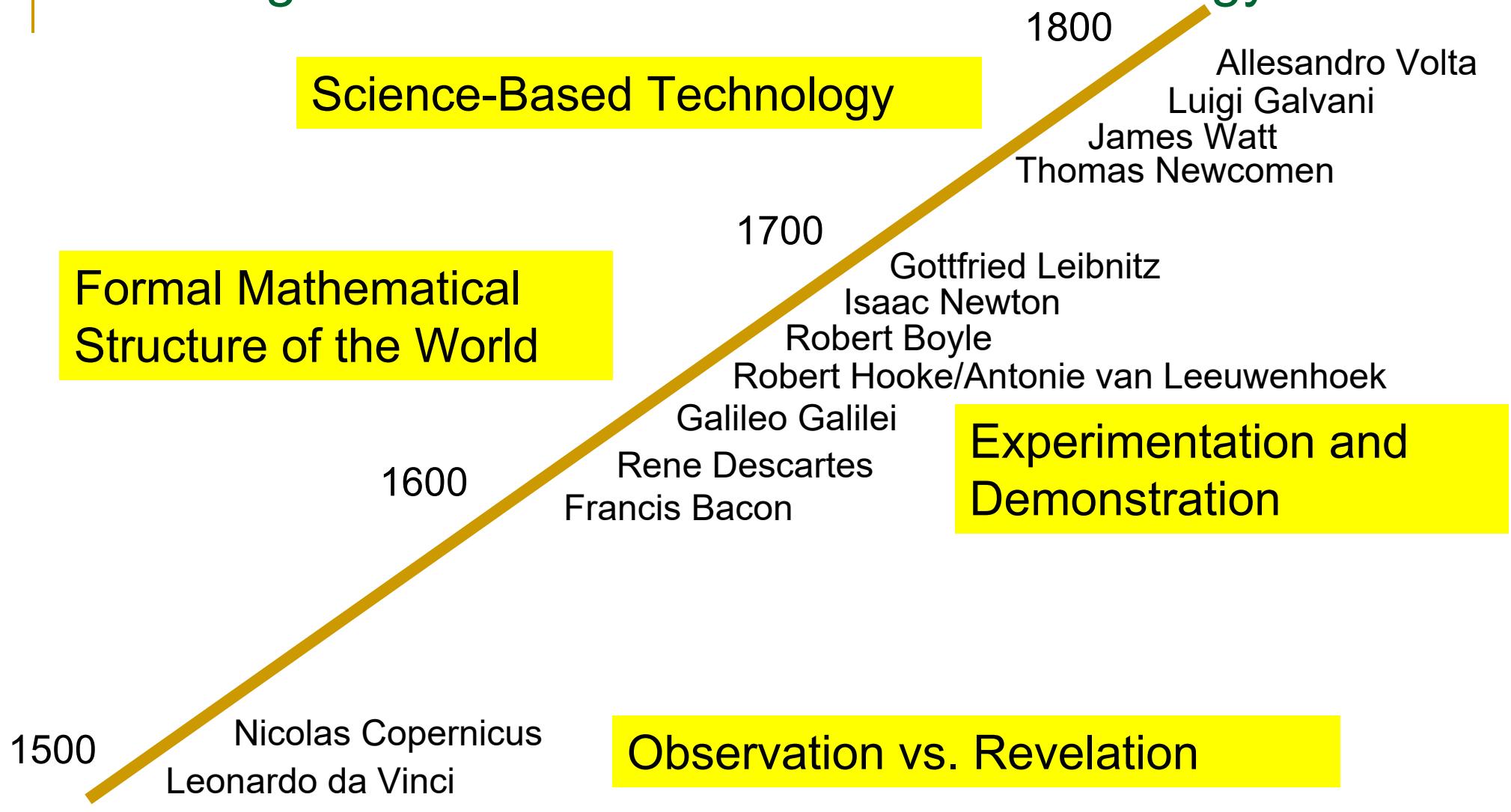
Nicolas Copernicus
Leonardo Da Vinci
Christopher Columbus/Amerigo Vespucci

Observation vs. Revelation

The Enlightenment: Separating Morals & Science



The Enlightenment: Basis of Modern Technology



The Enlightenment: Basis of Modern Technology

Science-Based Technology

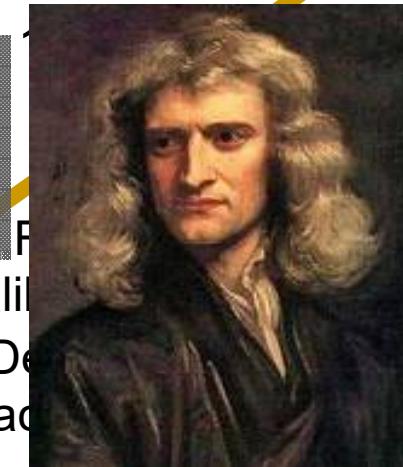
"If I can see further than other men,
it is because I stand on the shoulders
of giants."

Isaac Newton



"I think that in the discussion of natural
problems we ought to begin not with the
Scriptures, but with experiments and
demonstrations."

Galileo Galilei



1800
Allesandro Volta
Luigi Galvani
James Watt
Thomas Newcomen
Leibnitz
Rene Descartes
Francis Bacon
Galileo Galilei
Rene Descartes
Francis Bacon
Experimentation and
demonstration

The Enlightenment: Main Themes



■ Reason

“Men who are governed by reason - that is, who seek what is useful to them in accordance with reason - *desire for themselves nothing, which they do not also desire for the rest of mankind*, and, consequently, are just, faithful, and honorable in their conduct.”

Baruch Spinoza
Dutch Philosopher
1632-1677

The Enlightenment: Main Themes



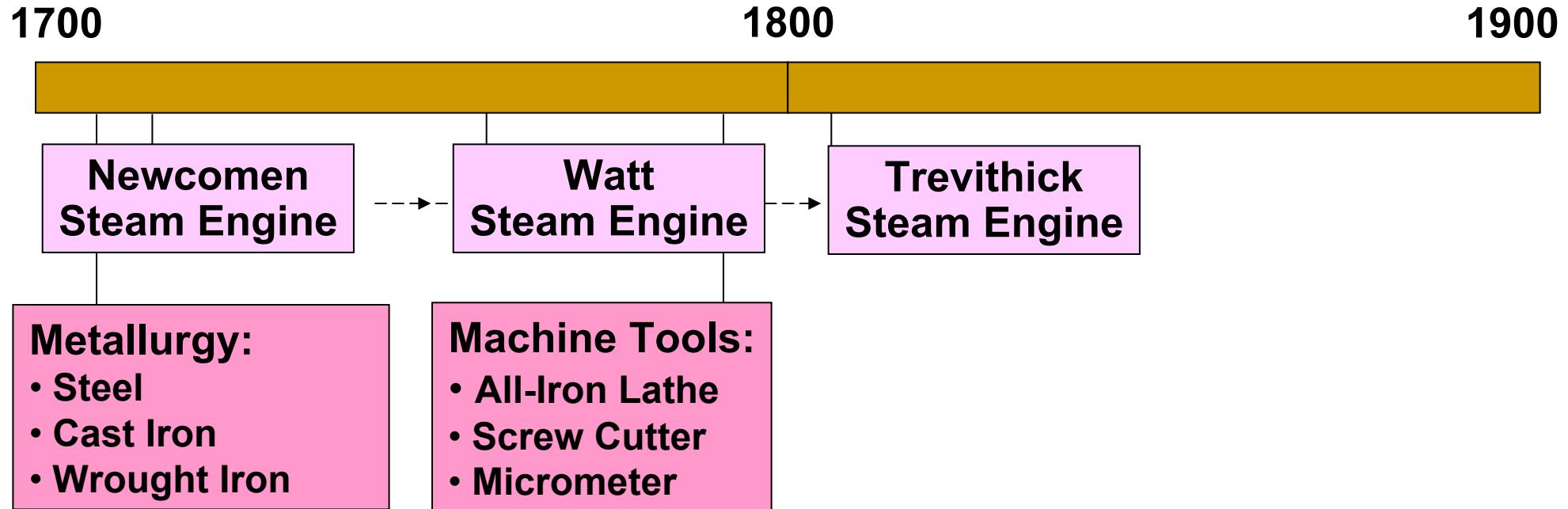
- Reason
- Science
- Progress



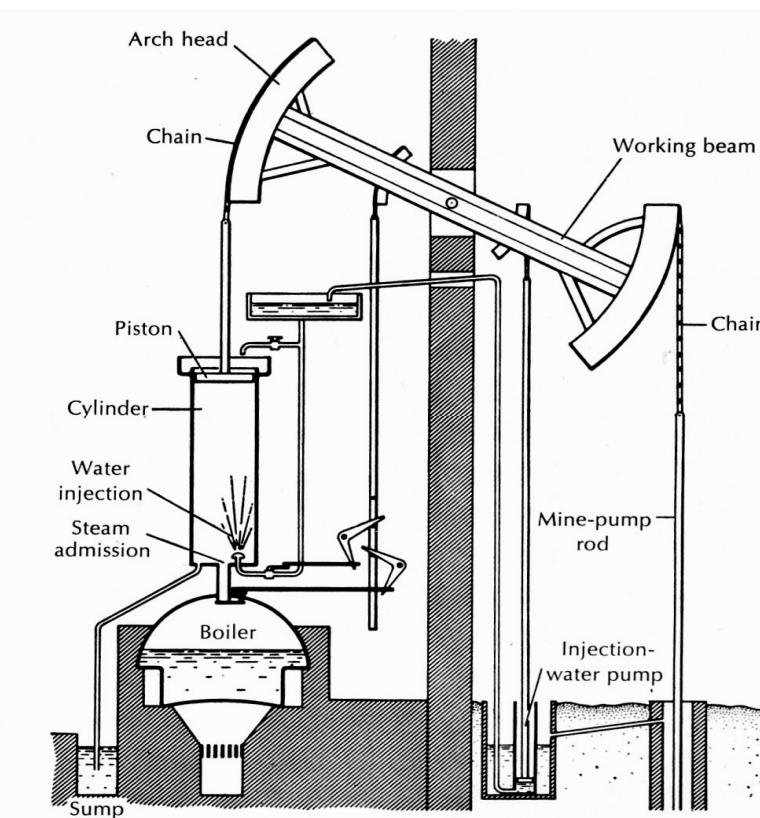
“The Scientific Revolution and the Enlightenment put in motion the process of using knowledge to improve the human condition.”

Steven Pinker
Research Psychologist
2016

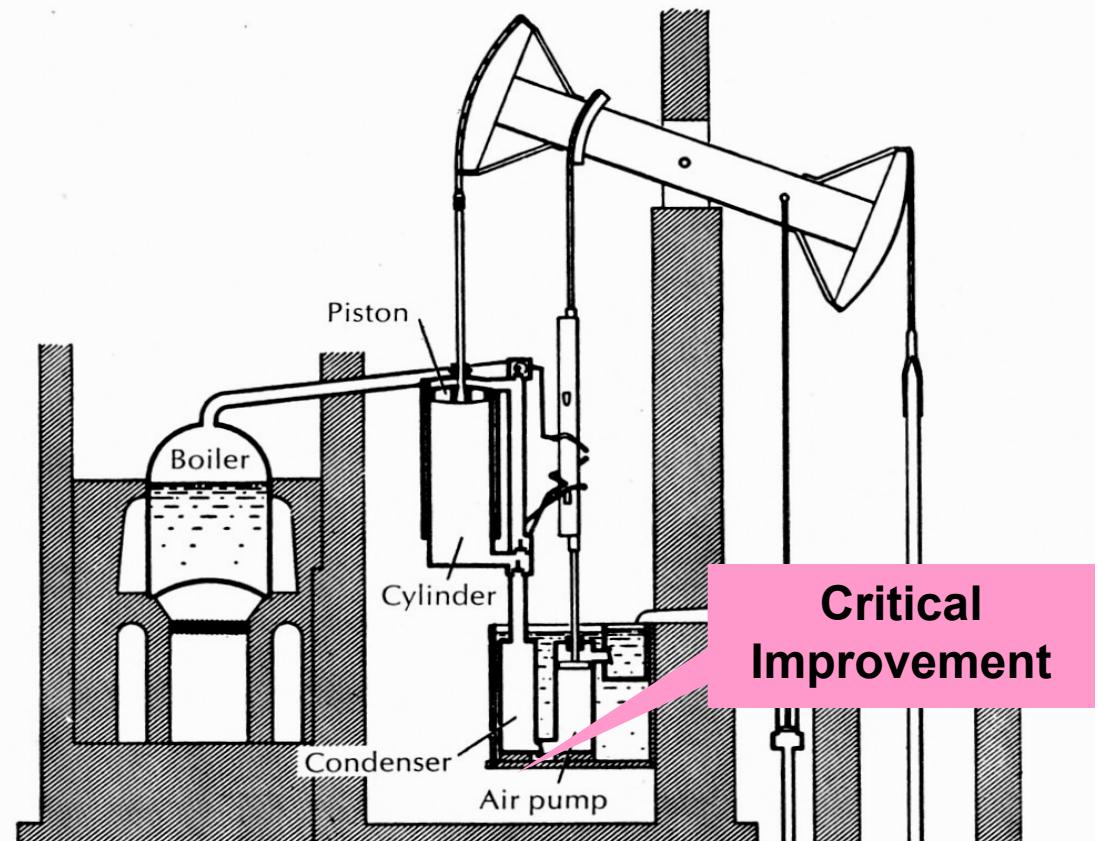
Industrial Revolution: Science Applied



Self-Contained Power



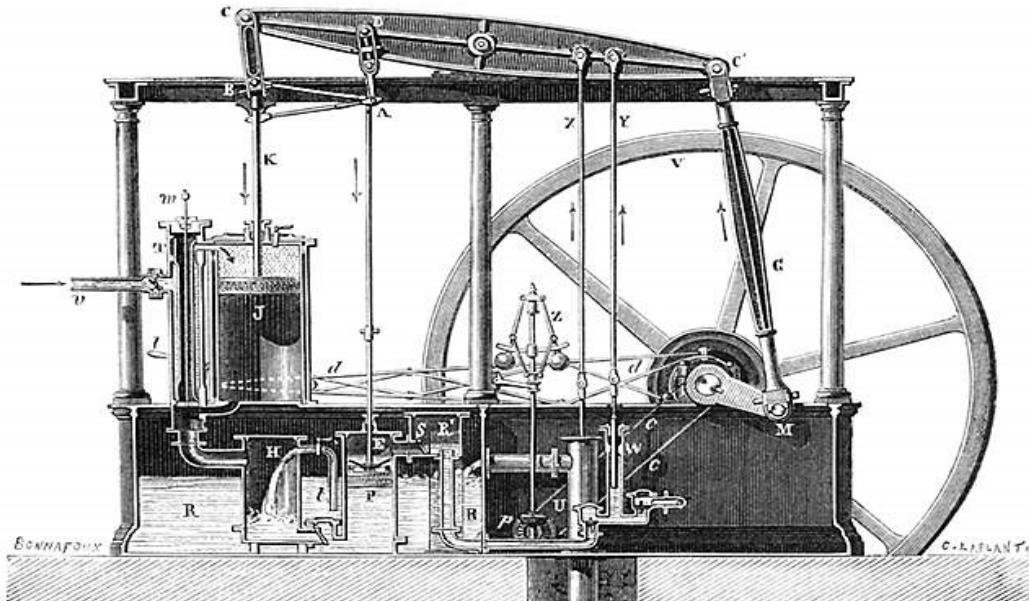
Newcomen Steam Engine (~1712)



Watt Steam Engine (~1765)

These are low-pressure steam engines

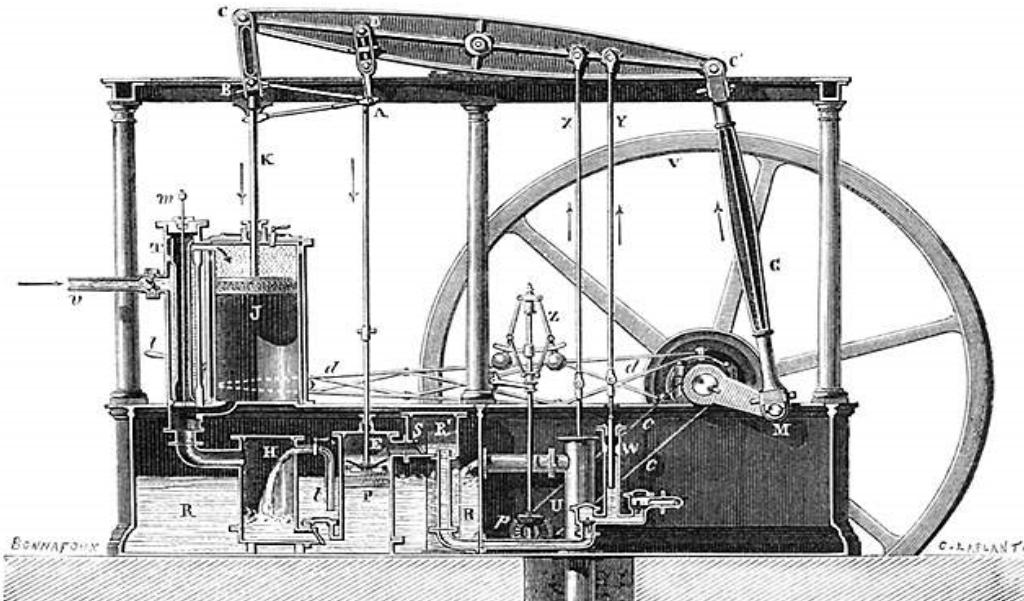
Rotary Motion from Steam



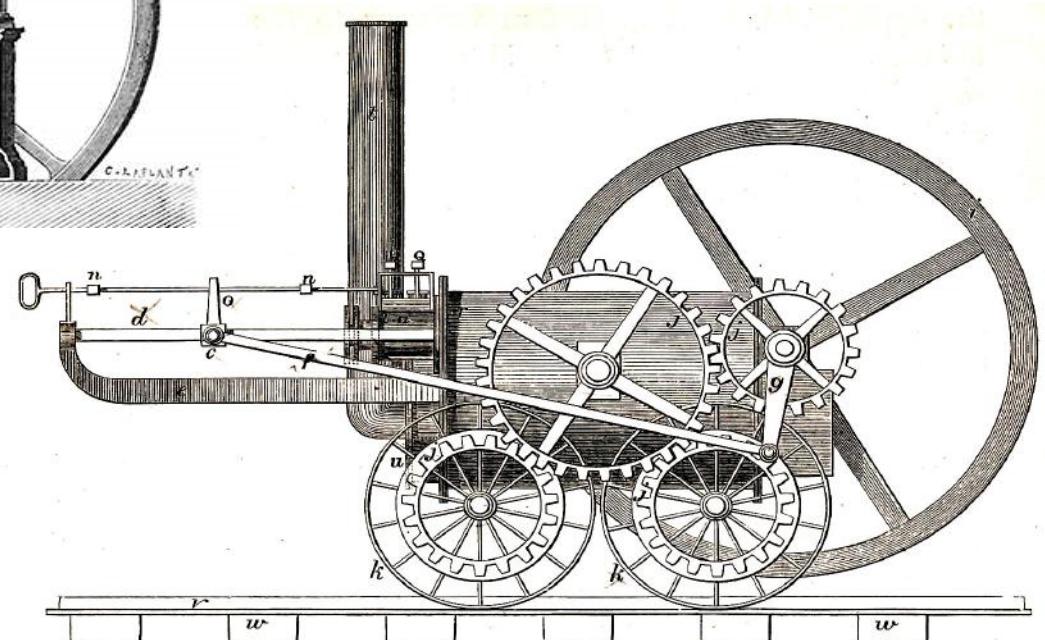
Watt rotary engine, c1785

Watt Image from: oldbookillustrations.com; [bankside.wikipedia](https://en.wikipedia.org/wiki/James_Watt); ICONS.A Portrait of England;
Trevithick image from: bing.com/images

High Pressure Steam Power



Watt rotary engine, c1785



Trevithick steam locomotive, c1804

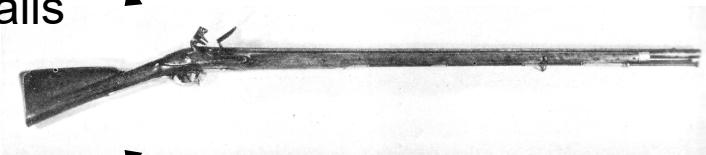
This is a high-pressure steam engine

Watt Image from: oldbookillustrations.com; bankside.wikipedia; ICONS.A Portrait of England;
Trevithick image from: bing.com/images

Interchangeable Parts

■ “The American System”

- Eli Whitney (Cotton Gin) proposes new system
- 1798 contract for 10,000 rifles from interchangeable parts
- Whitney fails but U.S. Army bails him out

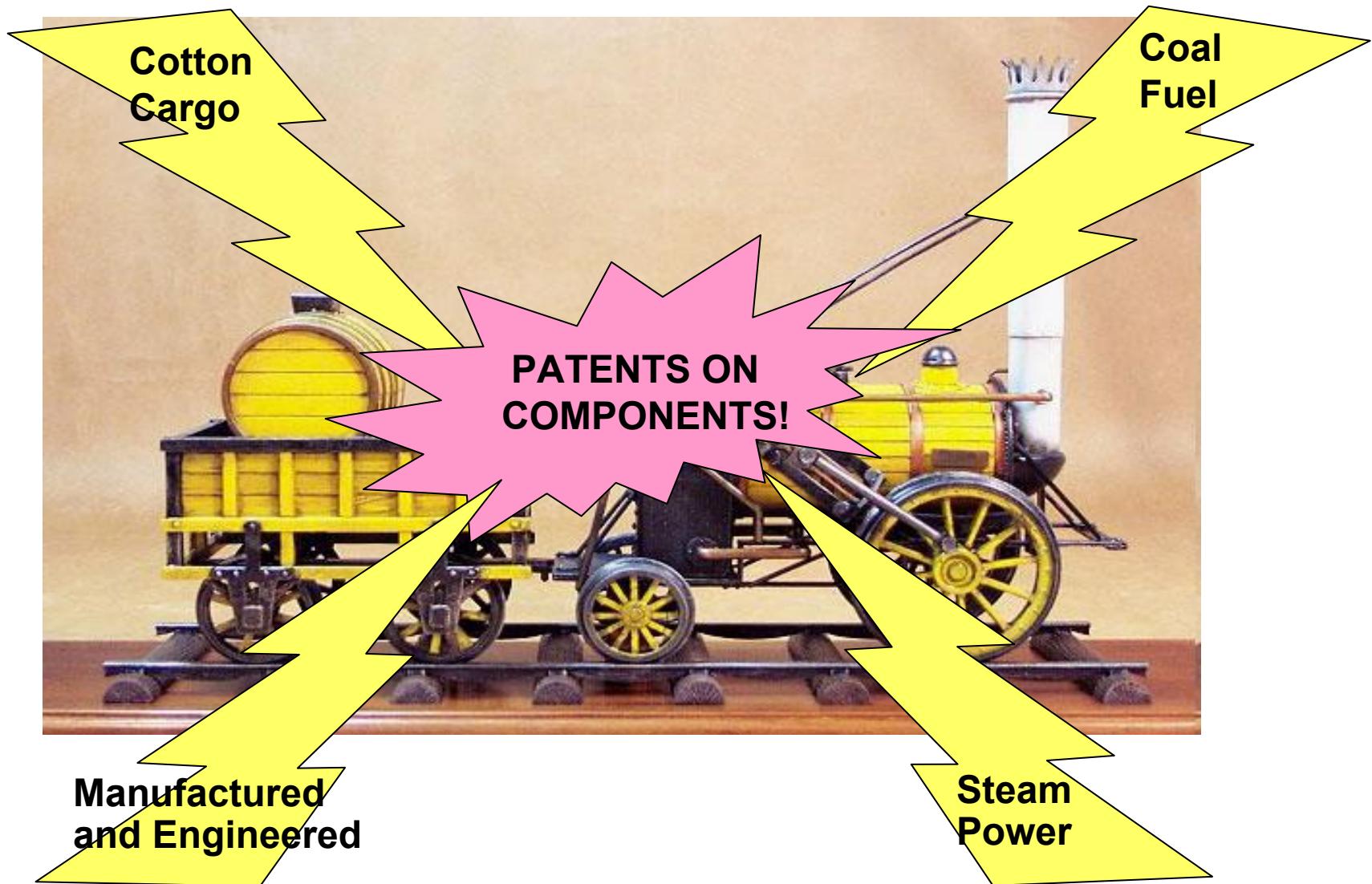


■ The Consequences

- U.S small arms industry listens, but no one else in U.S. does
- England enthusiastically adopts the methodology
- England shows off at 1851 Crystal Palace Exhibition
- Other countries rush to catch up



1829 Stephenson “Rocket:” An Industrial Summary



Ethical Implications of Patent Law

■ New Rights

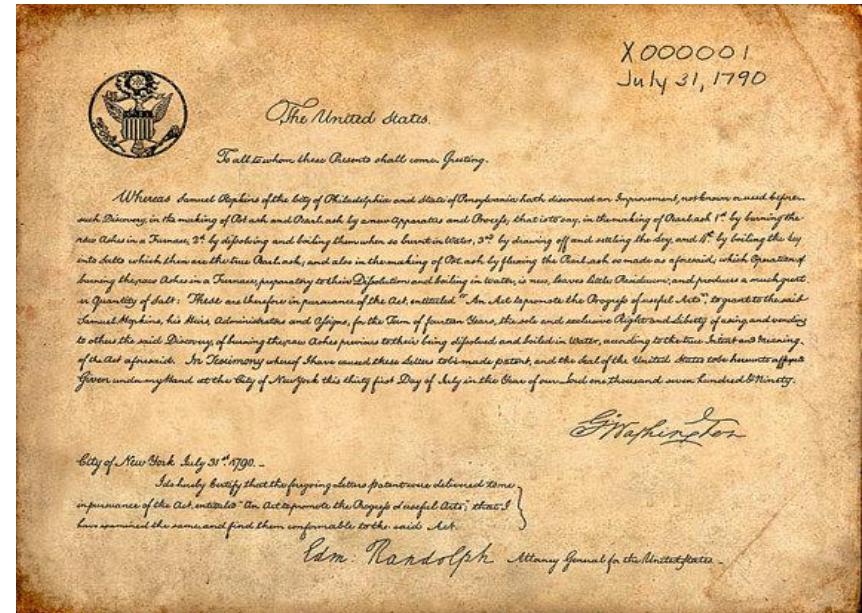
- “Intellectual Property”
- Everyman vs. Aristocrats
- Personal & Societal Benefit

■ New Duties

- Respect for patents
- Ethical use of inventions
- Promulgation of knowledge

■ Other Consequences

- Industrial monopolies
- Power of nations
- Colonized world



First United States Patent signed by George Washington on July 31, 1790, to Samuel Hopkins for making potash, a component of fertilizer

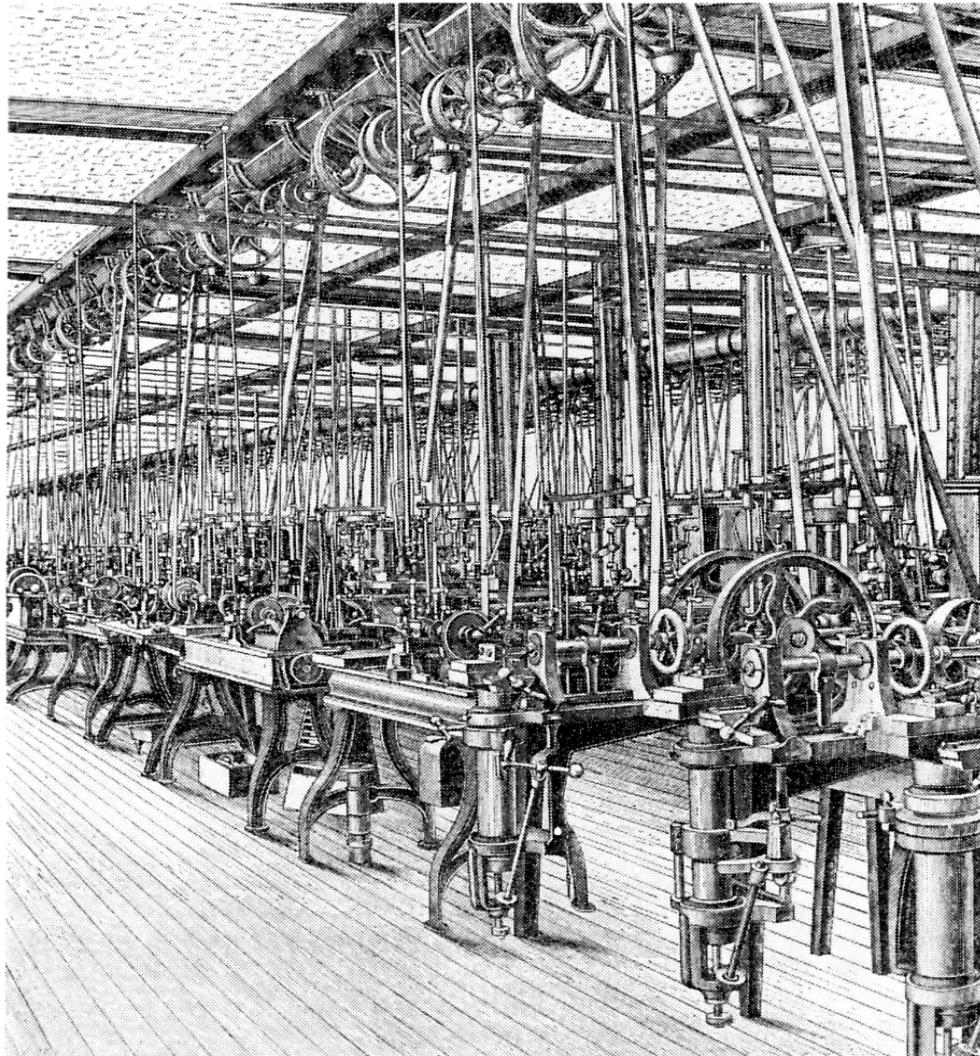
Hot Air Flight: A Dream Realized



Montgolfier flight, Paris 1783

The goal of flight is achieved at last by three animals in a hot air balloon. Hot air and hydrogen balloons soon included human ascents and excursions.

Factories Producing Interchangeable Parts

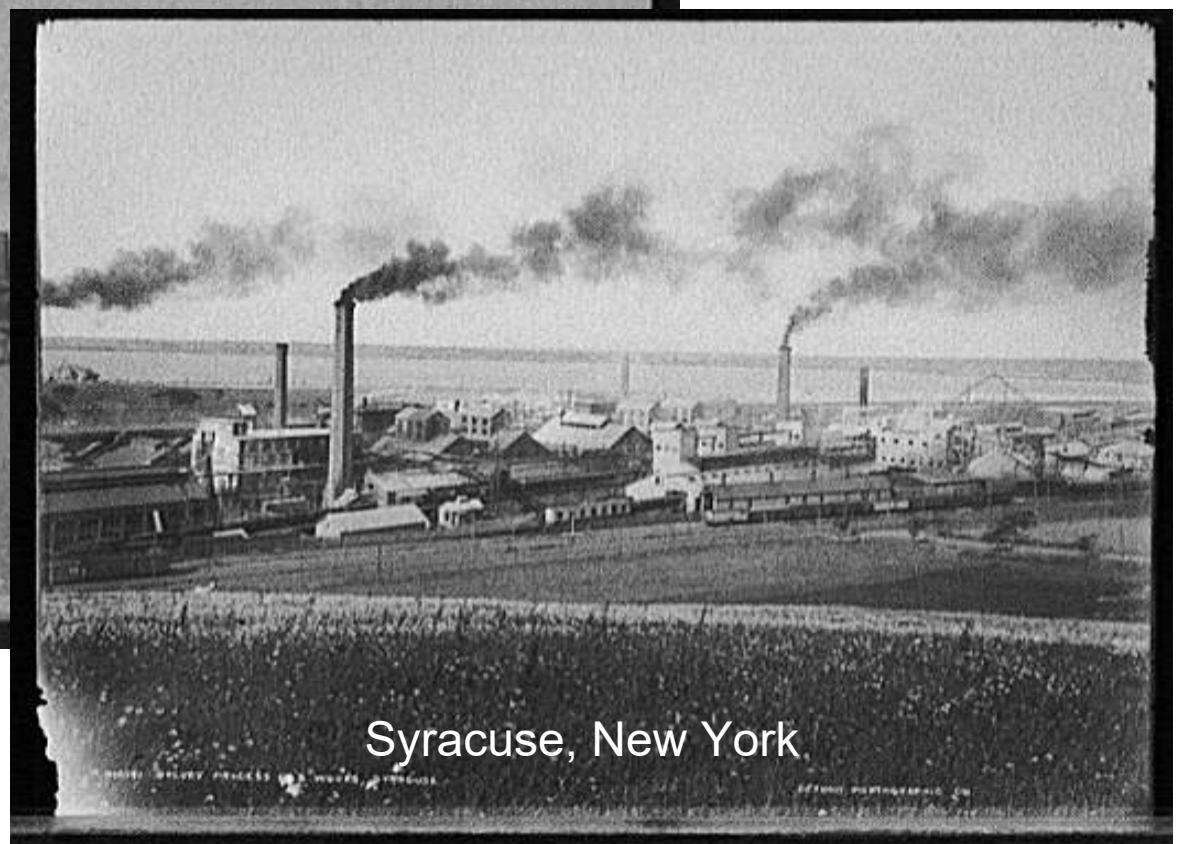


U.S. Colt Company arms factory showing lines of leather belt-driven machine tools making interchangeable parts for Colt revolvers and rifles

Rise of the Industrial City

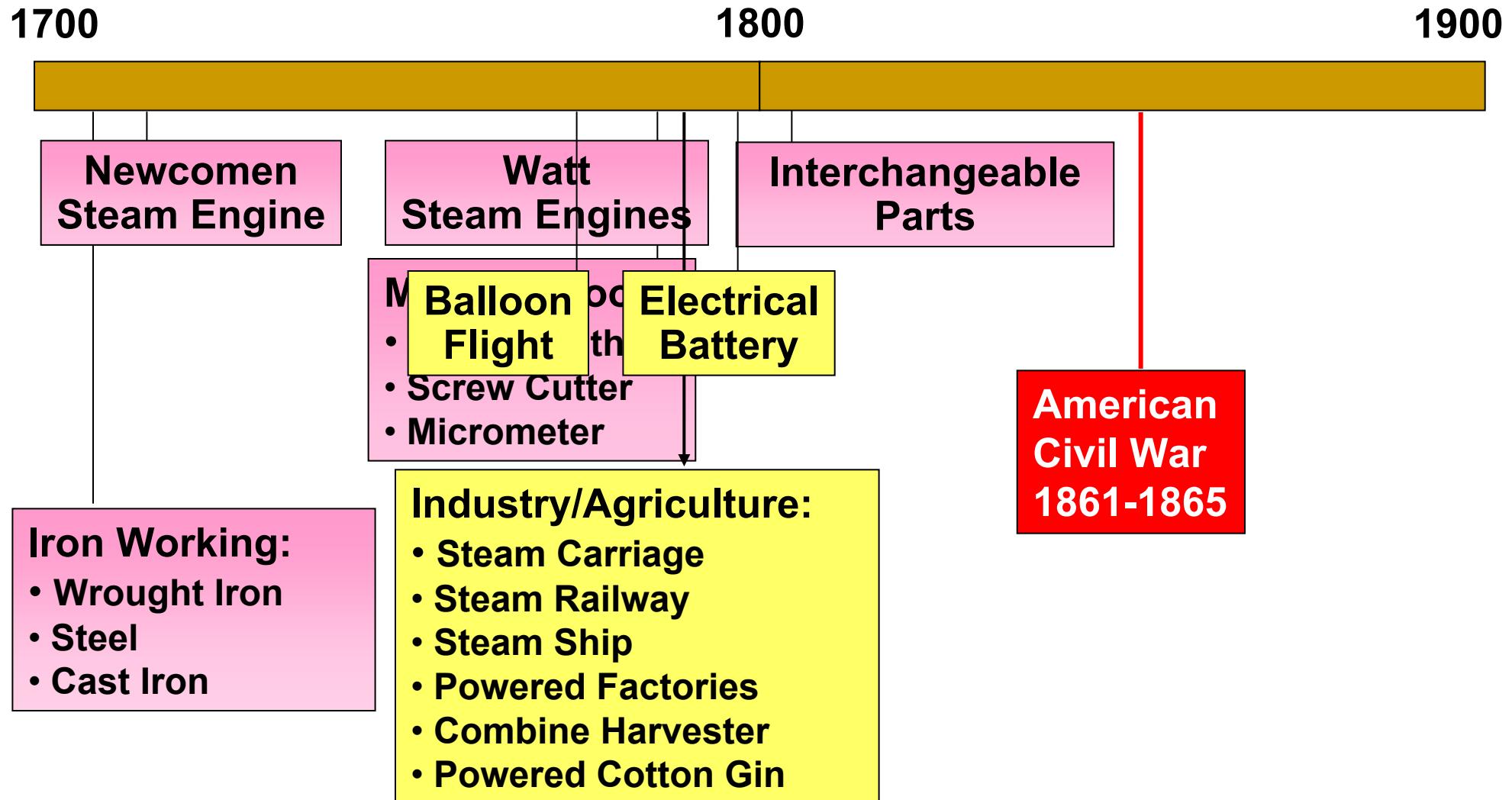


South Chicago, Illinois

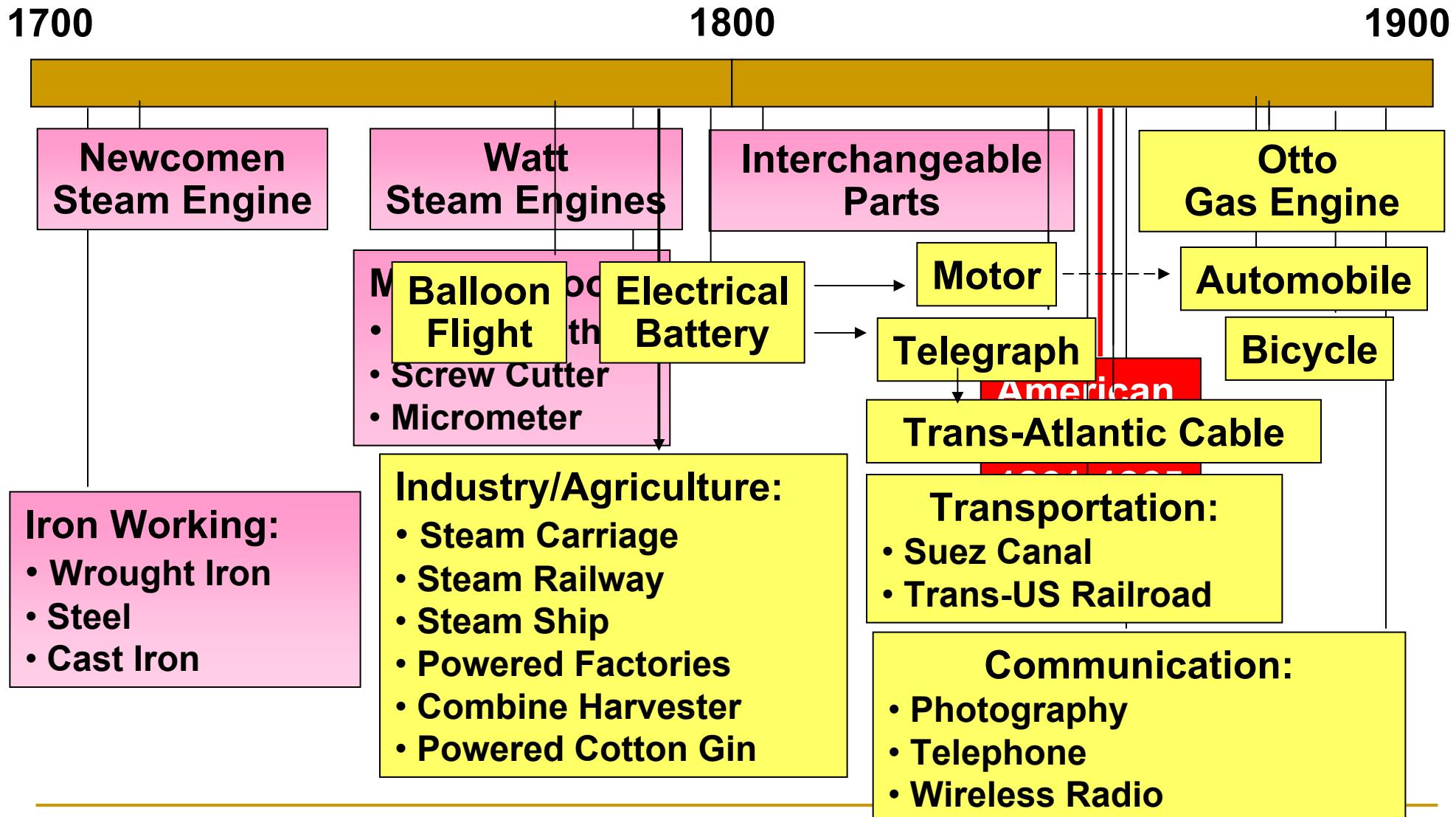


Syracuse, New York

Industrial Revolution: Changing the World



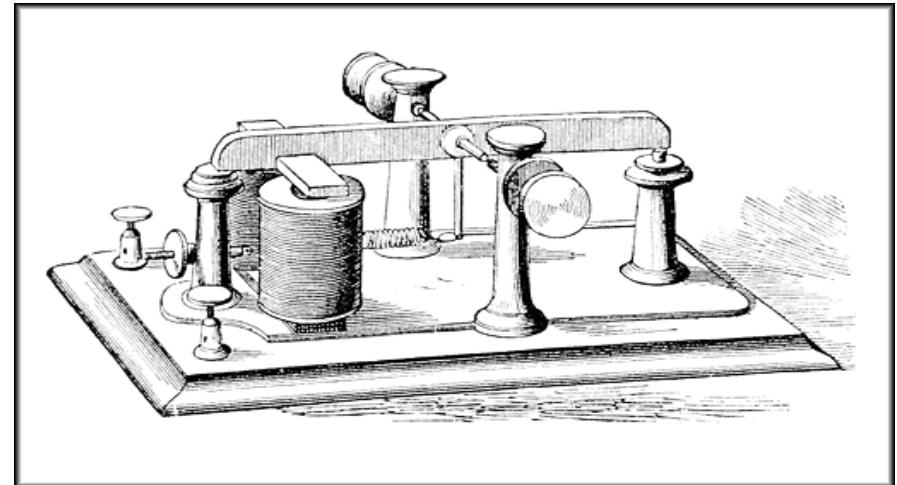
Industrial Revolution: Changing the World



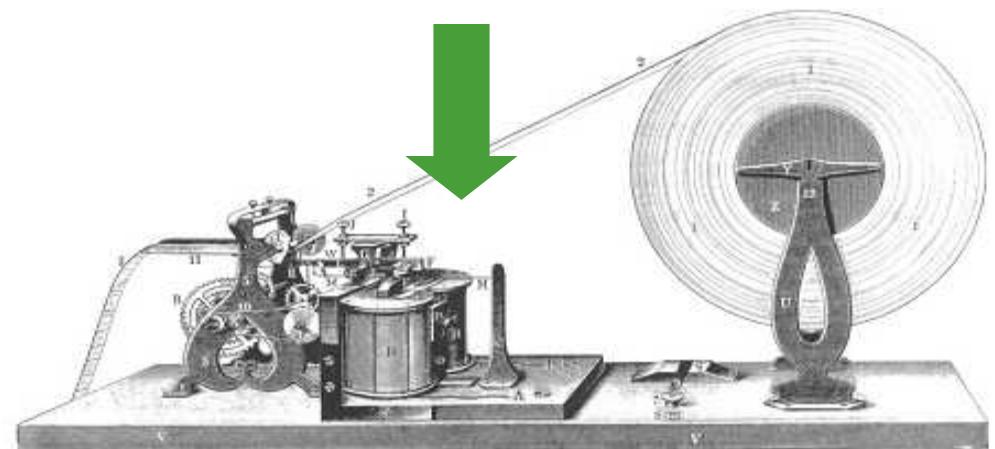
Electricity: Telegraphic Communication



Voltaic Cell, 1800

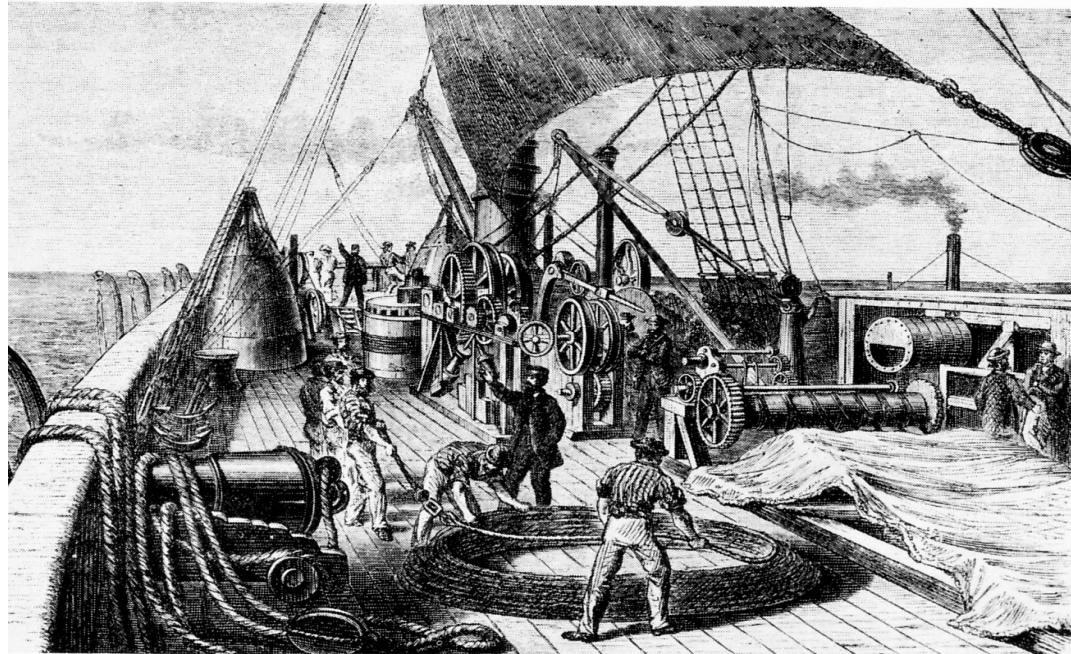


Henry Telegraph, 1837



Morse Telegraph, 1838

Telegraph: Instant Worldwide Connection



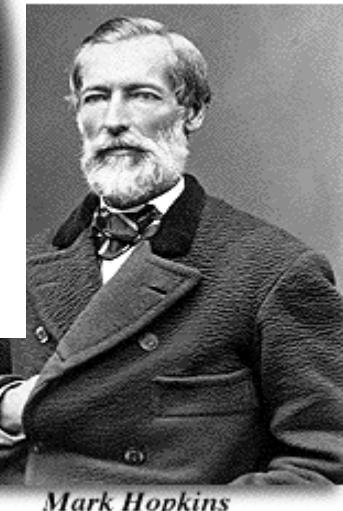
Laying the Trans-Atlantic Cable
1857 - 1866



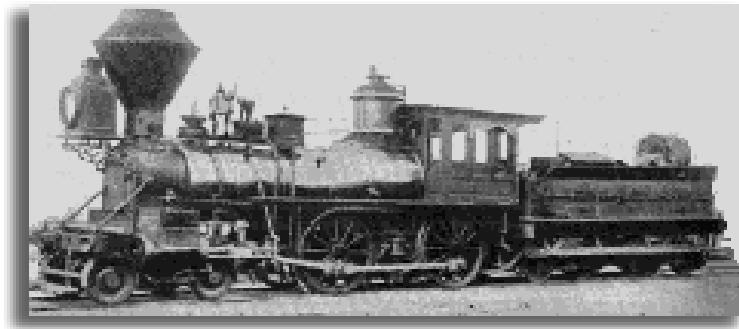
Continental Railroad: Transamerica Movement



C. P. Huntington

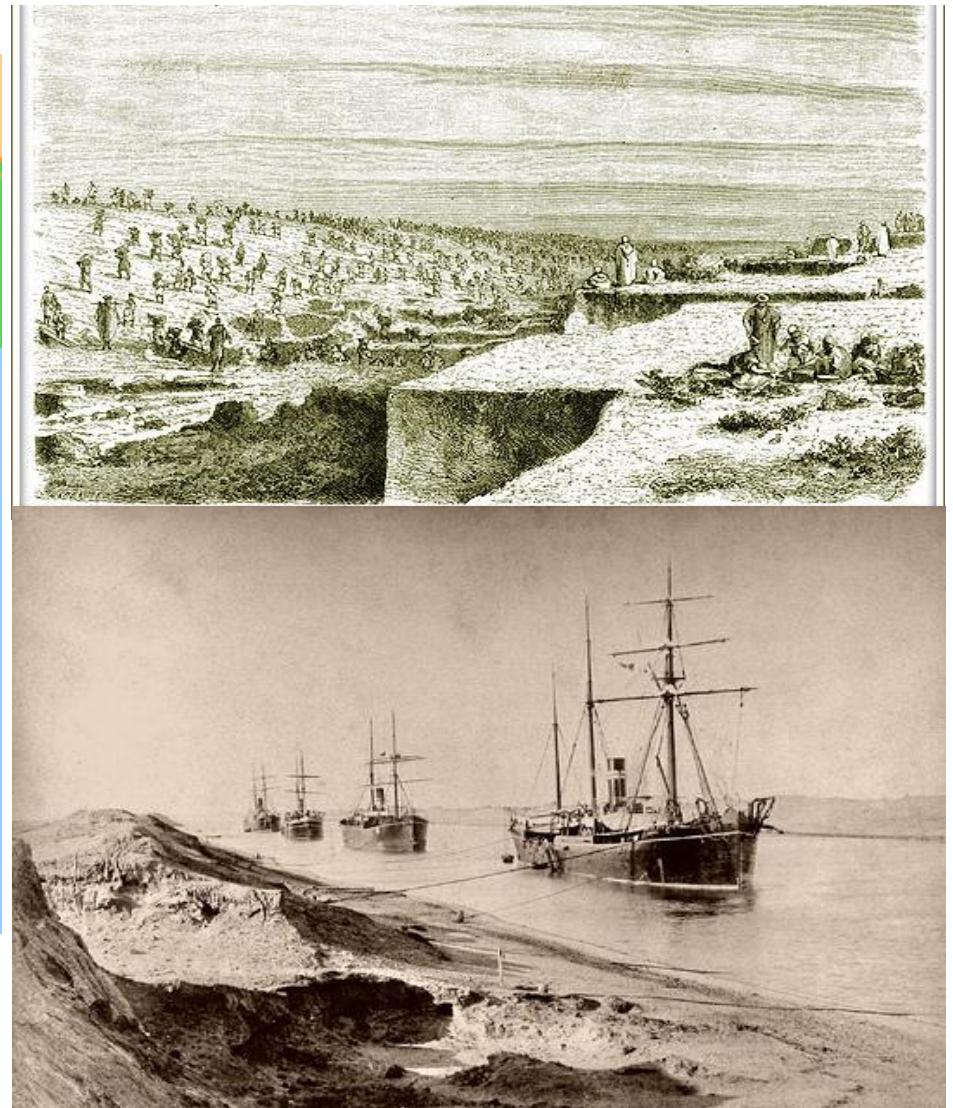


Mark Hopkins



The last rail is laid, 1867

Suez Canal: Transoceanic Passage



European engineering and local labor connect shipping East to West in 1869

Light and Sound Recording: High Fidelity History



Civil War Photograph (1862)

<http://www.flickr.com/photos/7735968@N08/3239688199/>



Edison Phonograph (1877)

<http://www2.hu-berlin.de/humboldt-forum/kabinette/forum/>

Edison
Kinetoscope (1897)

<http://www.yahoo.images.com>



For the first time society has accurate records of things as they are, and – most important – of things as they used to be many years ago

Motors: Motion from Electricity



1881 Griscom Motor



1890 Edison Motor

Individual Transport: Electric Powered



1884 Electric Carriage

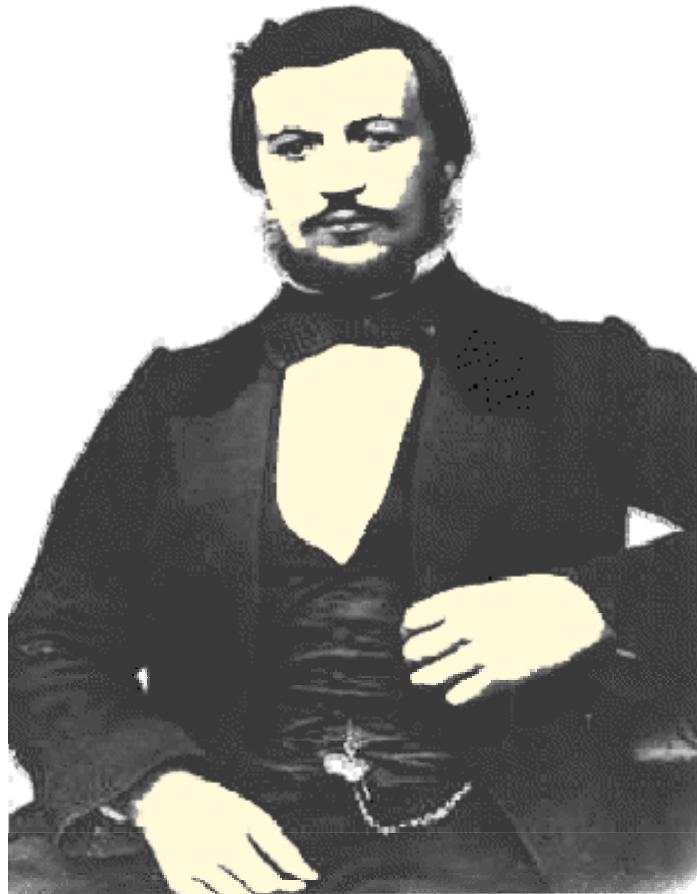


1896 Electric Dog Cart

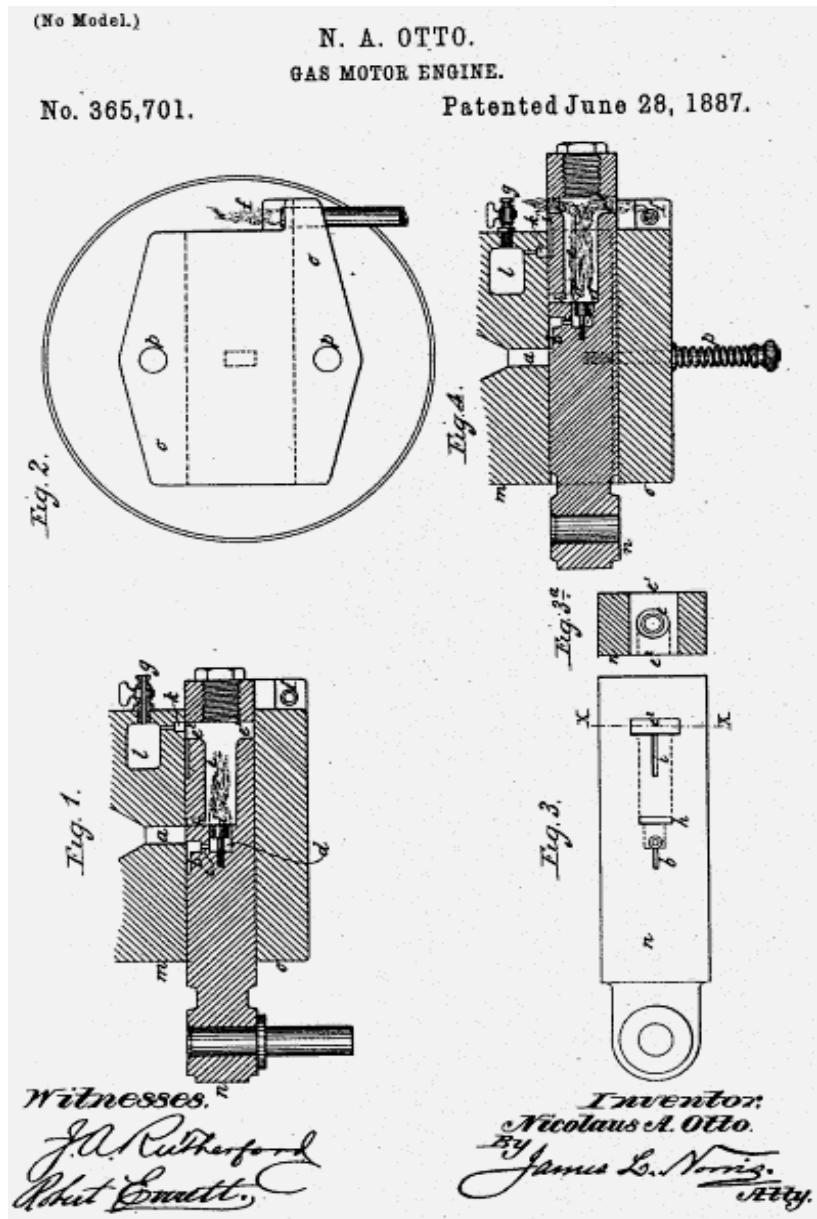


**ELECTRIC
CONSTRUCTION
COMPANY LTD**

Gasoline Takes Over



Nicolaus August Otto's 1887 Patent



Individual Transport: Gasoline Vehicles

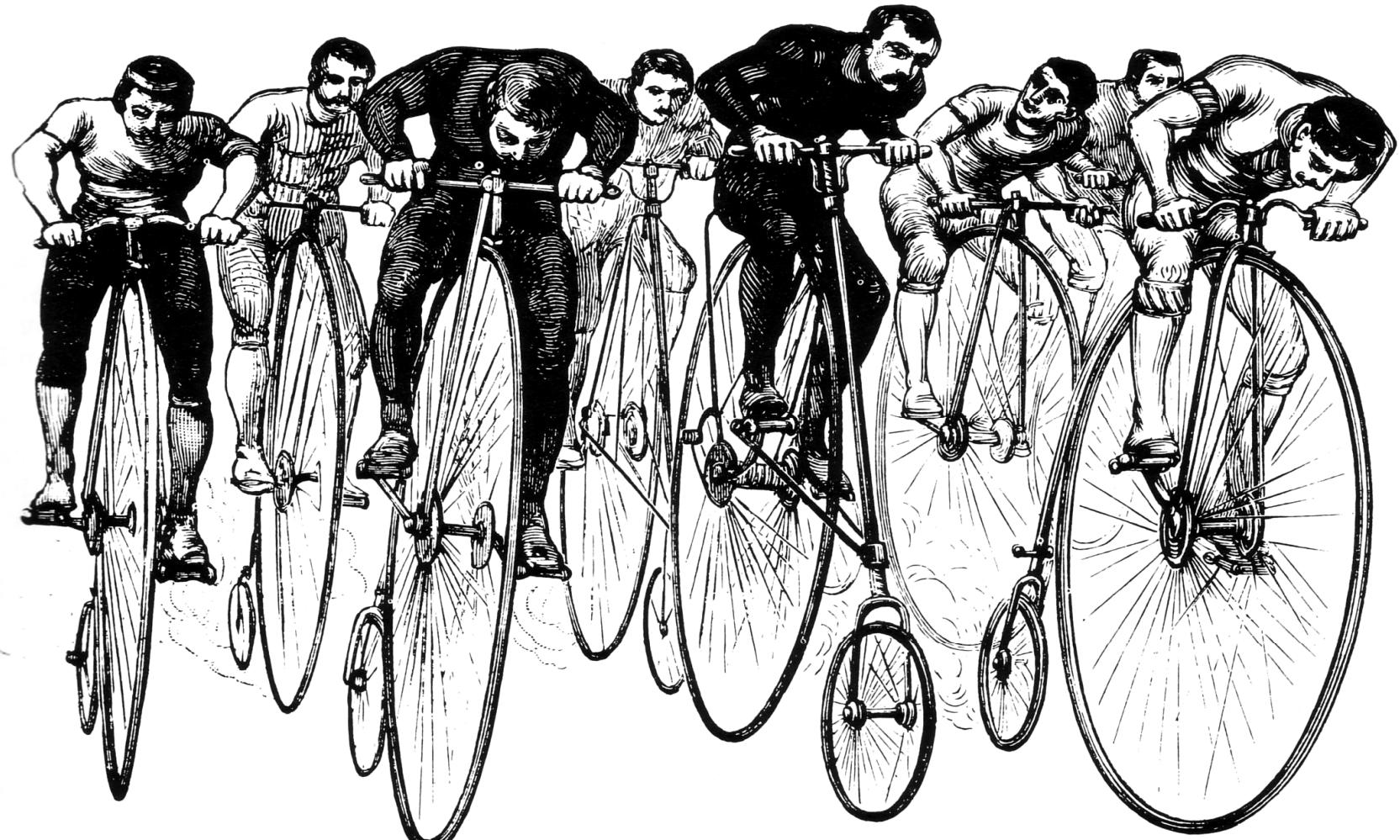


1885 Daimler Gas Motorcycle



1888 Benz Gas Motor Car

Individual Transport: Pedals and Legs



The “Ordinary” Bicycle (1880s)

Leonardo Again?



1817 Karl von Drius' Velocipede
was always considered 1st bicycle



1490 Leonardo da Vinci Bicycle
Sketch found in manuscript.
Some say sketch is a fake,
but Dr. Weltman (and others)
believe it is truly Leonardo's.

Bicycle's Effects on Society

- Affordable Mobility
- Demand for Roads
- Skills of Mechanics
- Role of Women

Women held records in racing over both long and short distances and in touring activities. Their revealing bicycling costumes and aggressive sporting behavior contradicted many current societal standards.



The Safety Bicycle (c1895)

“The Dursley-Pedersen was the Rolls-Royce of its day, combining a fully triangulated frame with fine materials and impeccable workmanship.”

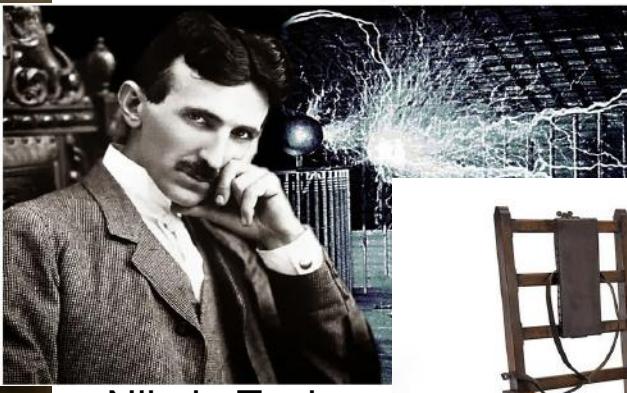
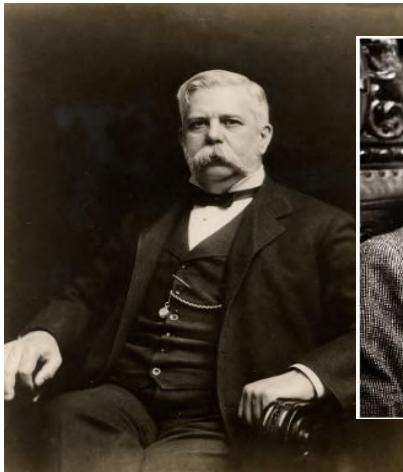
The High-Tech Bicycle, 1982



Experience with this type of refined bicycle technology provided valuable training for such innovators as the Wright brothers and Henry Ford

Power Distribution: Battle of Titans

AC vs. DC



Nikola Tesla



Thomas Edison



Electric Chair

George Westinghouse

Radio: “Telegraphy Without Wires”



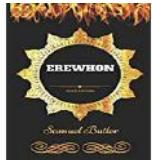
Guglielmo Marconi (1874–1937)



Early Crystal Radio Receiver, ~1898

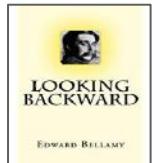
Mixed Moral and Ethical Visions

UTOPIAS



“Erewhon” by Samuel Butler, 1872

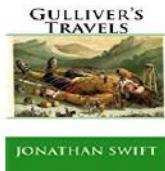
A future society where machines have been banished, criminals are sick, and the sick are criminalized



“Looking Backward” by Edward Bellamy, 1888

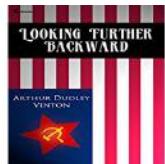
An ideal socialist society of 2000 where people share equally in the rewards of technology

DISTOPIAS



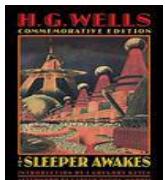
“Gulliver’s Travels” by Jonathan Swift, 1726

Gulliver visits the floating island of Lagado, where mad scientists are trying to make pincushions out of marble



Looking Further Backward” by Arthur Vinton, 1890

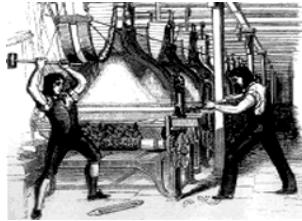
China invades the US, which has been weakened by socialism, to restore a capitalistic society



“When the Sleeper Wakes” by H.G. Wells, 1899

In the 21st century people are dominated by propaganda and ruled by a demagogue, but the sleeper is the richest man

Objections to Technology's Effects



Luddism (~1811)

Workers fight for the right to work against *displacement* by machine automation

John Henryism (~1870)

Workers fight for the right of personhood against *dehumanization* by machine

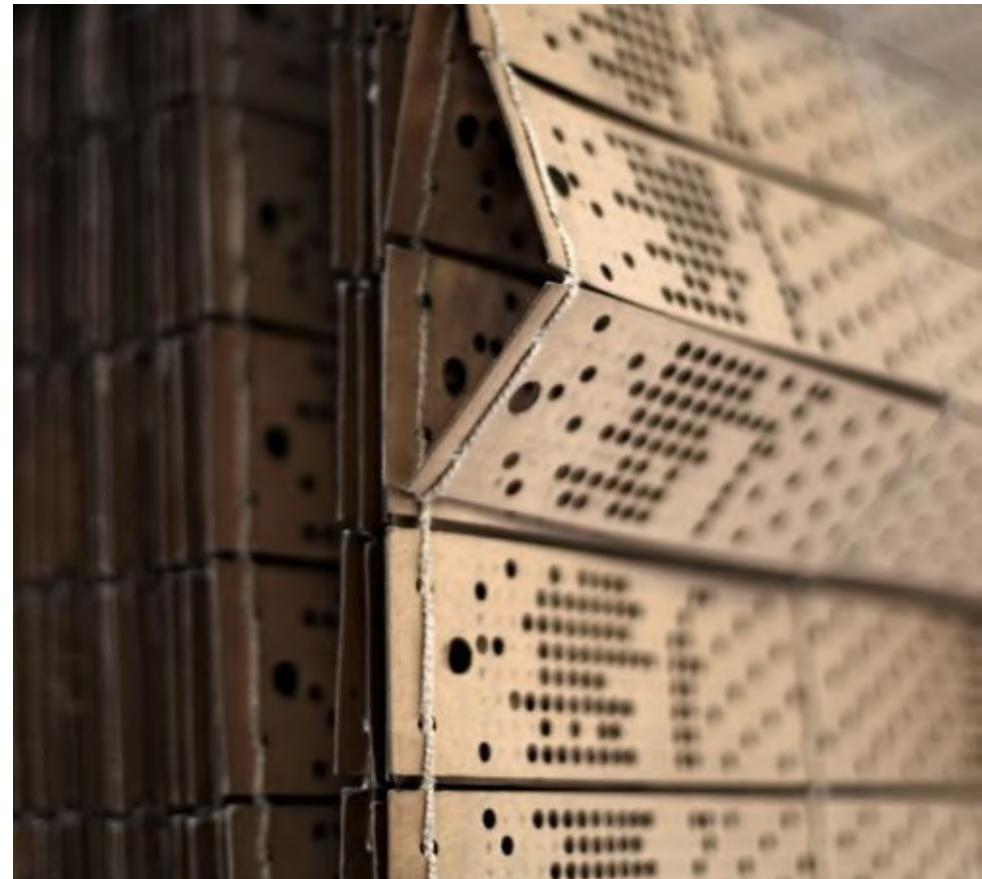
Restorationism (~1900)

Groups promote the value of historical human-centered craftsmanship against purely *industrialized* products

Luddism: Against Job Displacement

In 1811 workers upset by wage reductions related to “automated” looms and the un-apprenticed workmen who were able to man them began to break into factories at night to destroy the new machines.

Threatening letters were sent to employers in Nottingham. from General Ned Ludd and the Army of Redressers

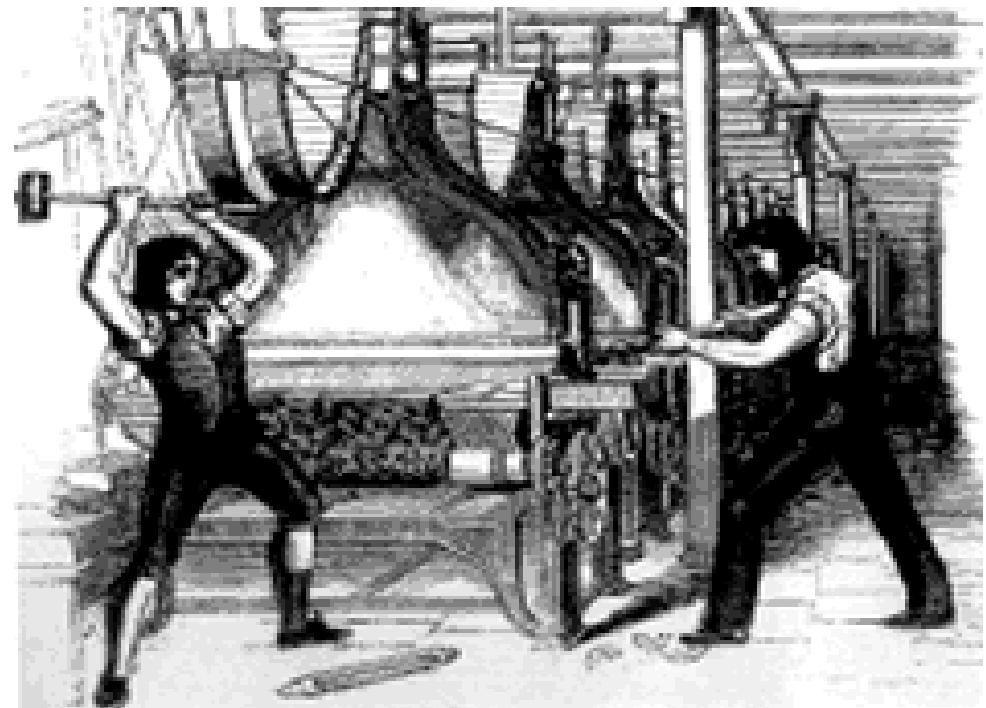


Luddism: Against Job Displacement

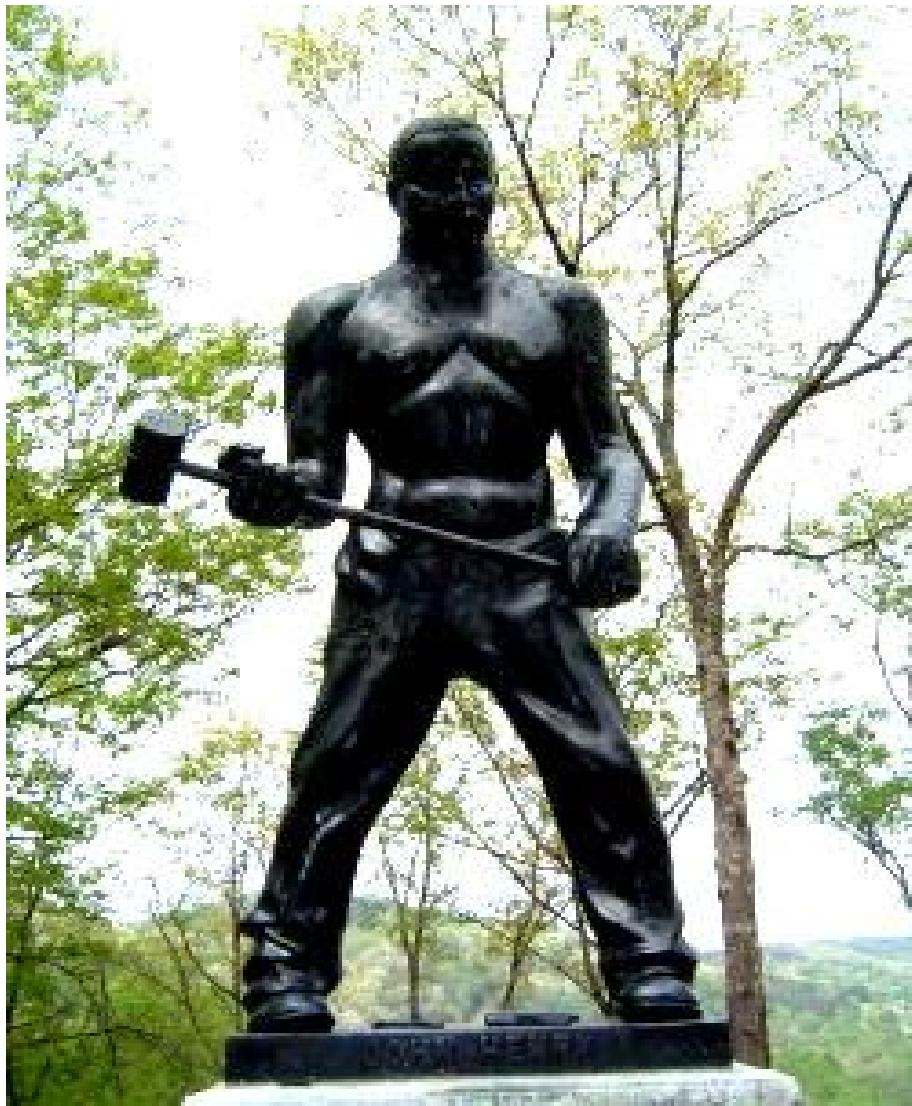
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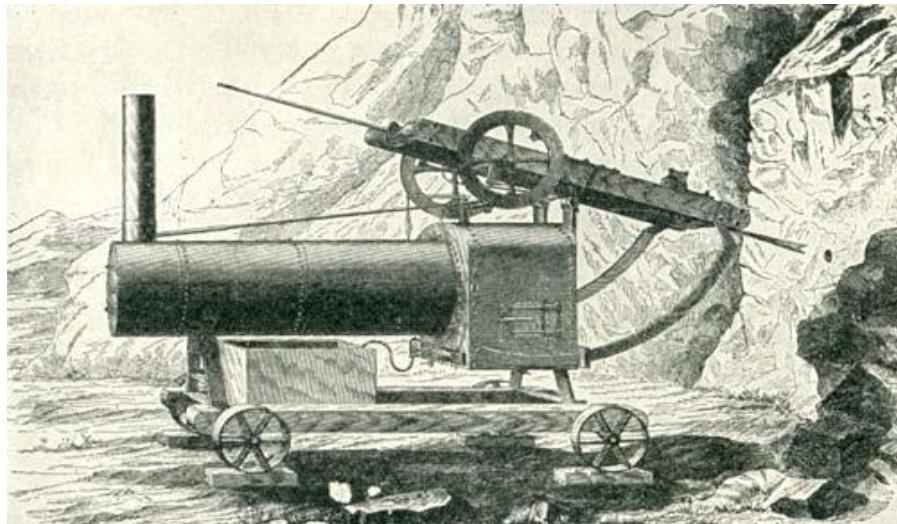
In a three-week period over two hundred weaving frames were destroyed. To help catch the culprits, the Prince Regent offered £50 to anyone “giving information on any person wickedly breaking the frames.”



John Henryism: Against Loss of Personhood



John Henryism: Against Loss of Personhood



*John Henry said to his captain
Now a man ain't nothin' but a man,
And before I'm gonna let
Your steam drill beat me down,
I'll die with this hammer in my hand,
I'll die with this hammer in my hand.*



Restorationism: Against Loss of Craftsmanship

Arts & Crafts Movement

- William Morris is driving force from England
- Objective is to value personalized design and production by hand
- Not so much to counter manufactured products as to recognize their roots
- Europe and USA included
- Home products as well as home architecture
- Anticipates designs of Art Deco and Modernism



Restorationism Today: Return to an Idealized Past



Real Victorian House
Los Angeles
Angelino Heights 1890



Replica Victorian House
Los Angeles
Chatsworth 1990

Others choose Renaissance Times, Medieval Times, Classical Times, etc.

Example Analysis: Pennsylvania Today

- Log in to UCLA_WIFI
- Go to <https://onlinepoll.ucla.edu>
- Search for [Engr183EW–Pennsylvania](#)
- Password: 1234
- Answer the 1 question
- Multiple choices are permitted
- Hit “SUBMIT”
- Finish in 3-5 minutes

Industrialization at the End of the 19th Century

- Energy Sources Coal, Wood, Petroleum
- Portable Power Steam, Electrical, Gas
- Mass Transport Shipping Lines, Railways
- Personal Transport Bicycles, Cars
- Communication Telephone, Film, Records, Radio
- Agriculture & Food Combines, Mills, Refrigeration
- Manufacturing Diverse factories in Industrial Cities
- Military Rapid-Fire Guns, Armored Vehicle
- World Society Colonialism, *Industrialized* vs. Not, Restricted Democracy & Rights
- Technology Driving Force Worldwide

Most, but not all, of the essential components for the *Modern World*