

Ecology and Sustainable Development.

SS 2025

1. Human Development
2. Ecology and Ecosystems
3. Ecosystem Functions
4. Concept of Sustainable Development
5. Environmental Pollution
6. Natural Resources
7. Climate Change
8. Socioeconomic Challenges
9. Third Industrial Revolution

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Ecology and Sustainable Development.

R



**Joint Research
Centre
European
Commission**

**Institute for
Environment and
Sustainability**

Ispra

**500 staff
annual budget
100 million EUR**

Literature, References and Acknowledgements.

- **Recommended Literature:**

- **Jay H. Withgott, Matthew Laposata:**

Environment: The Science behind the Stories, 7th Edition 2020

- **Wikipedia:**

An very useful source of information on virtually all issues dealt with in the lecture course. Occasional inaccuracies may occur since the content of the articles is not validated.

- **References:**

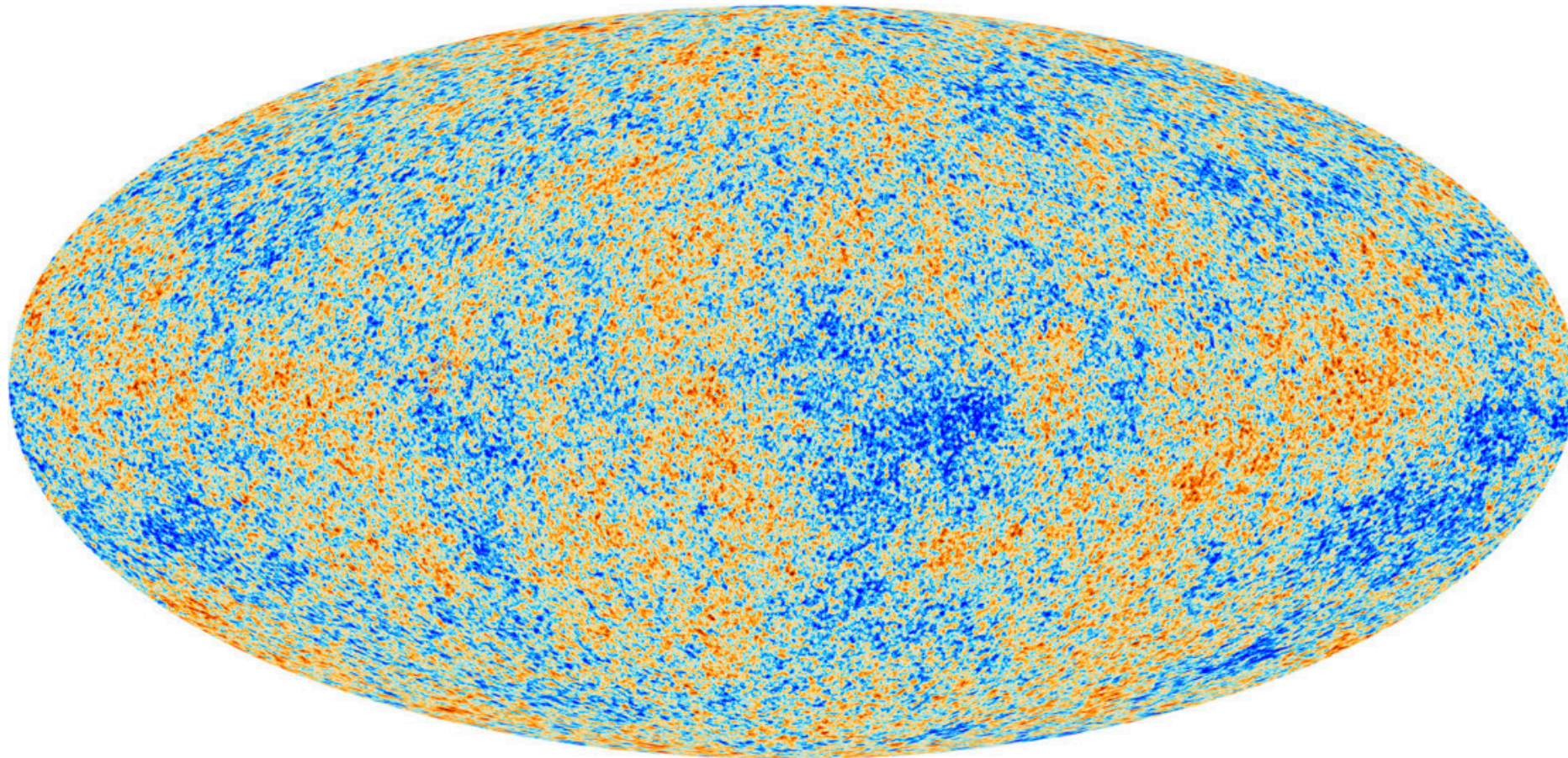
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- **Acknowledgements:**

- Material from this lecture course has been obtained from many different sources, particularly from international institutions active in this field like UNEP, the IPCC, WHO, the European Environment Agency, The Joint Research Centre of the European Commission, etc., and also from Wikipedia which provides excellent articles on many topics of interest in this context. The possibility to obtain information from these sources for this course is gratefully acknowledged.

The Universe.

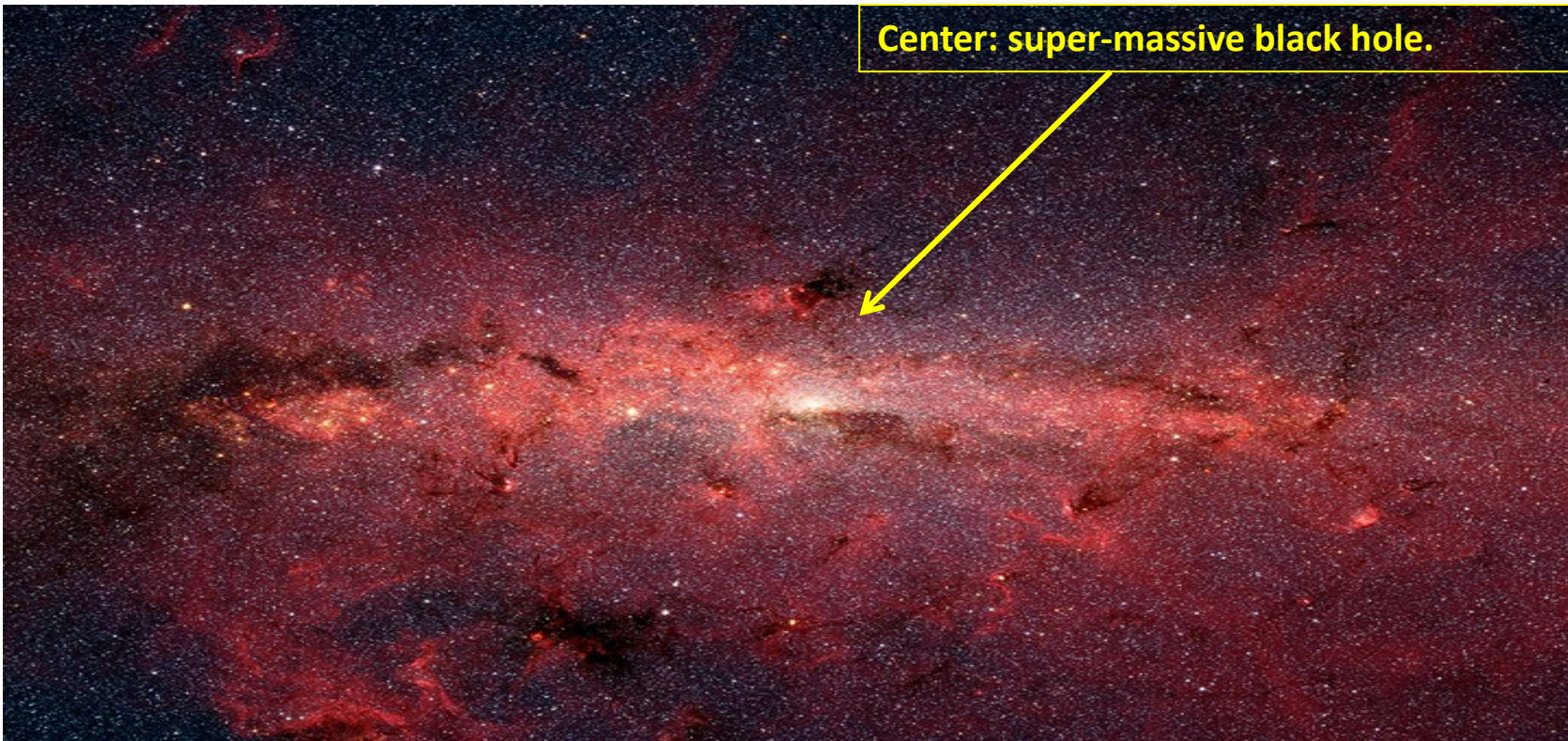
- The **Universe**: the totality of existence, including planets, stars, galaxies, the contents of intergalactic space, subatomic particles, and all matter and energy.
- Began 13.82 billion years ago through the “Big Bang” which delivered all the energy contained in our present universe.



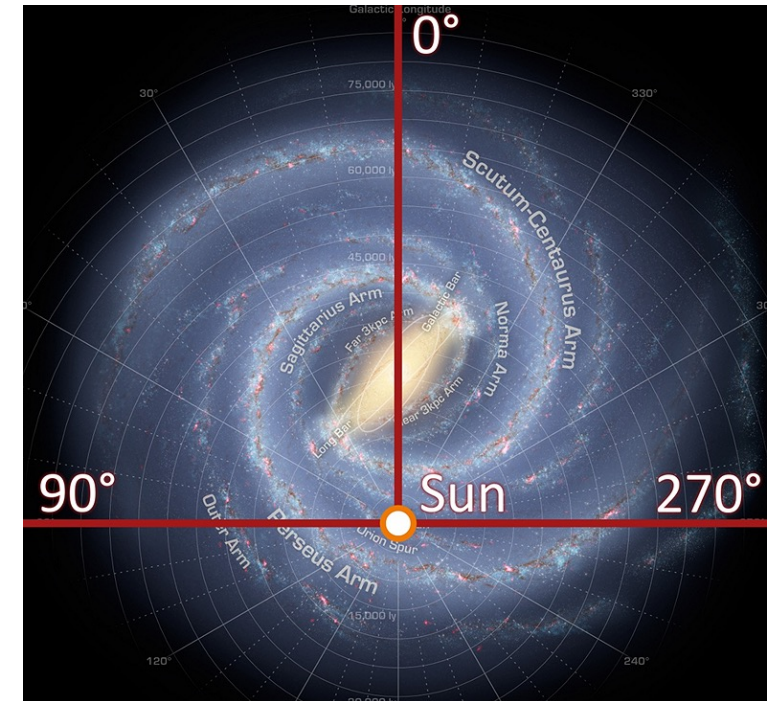
Space Telescope
Planck (2009-2013):
cosmic background
radiation in range
30 und 857 GHz.
Position 1,2 mio km
distance from earth.

The Universe and our Galaxy.

- There are probably more than 100 billion (10^{11}) galaxies in the observable Universe.
- **Our Galaxy:** the “Milky Way”
 - 200-400 billion stars and at least as many planets, 10 billion of which could be located in the habitable zone of their parent star.
 - 13.2 billion years old, nearly as old as the Universe.
 - The entire Galaxy moving with ca. 600 km per second (2 million km/h).

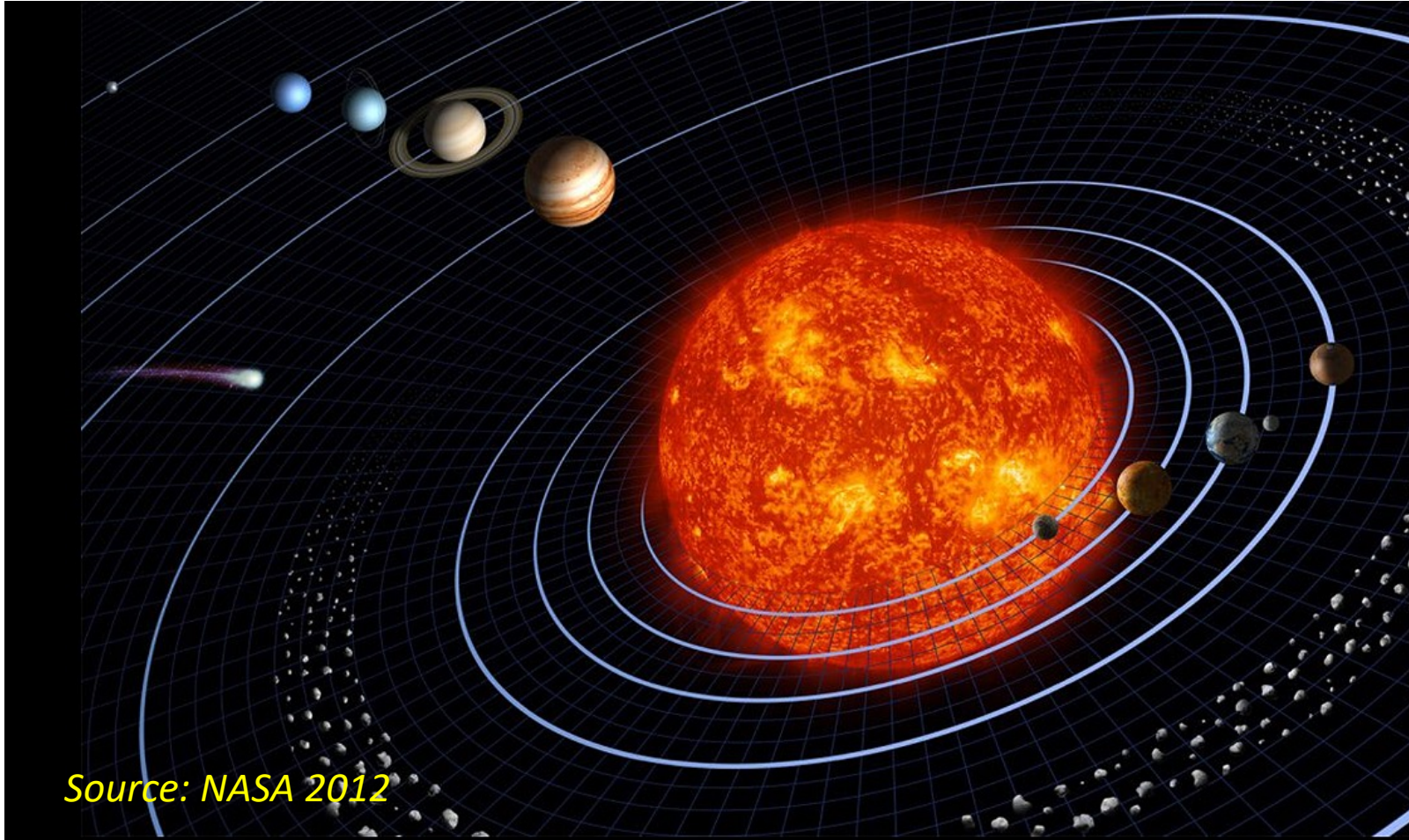


Diameter 900.000.000.000.000.000 (9×10^{17}) km. Thickness: 9×10^{15} km.

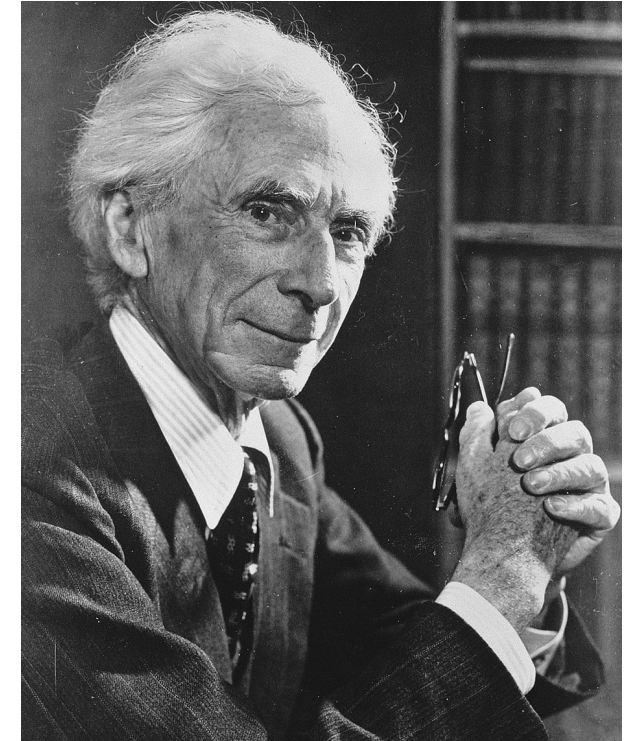


Distance of sun from center:
ca. 3×10^{15} km.

Spaceship Earth.



- Our solar system has 8 planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune) and a diameter of 6.000.000.000 km.
- The diameter of earth is 12.000 km.
- Earth is the only planet with living objects.



Bertrand Russel (1872-1970)

History of Western Philosophy:

“Is man what he seems to the astronomer, a tiny lump of impure carbon and water crawling on a small and unimportant planet?”

Our Sun.

- Ball of plasma: hydrogen (73%) and helium (25%)
- Formed ca 5 billion years ago from a collapsing molecular cloud.
- Radius 695.700 km
- Core temperature: 15 million °C
- Reactions in core:
nuclear fusion (proton chain)
 ${}^1\text{H} + {}^1\text{H} = {}^2\text{H}$
 ${}^2\text{H} + {}^1\text{H} = {}^3\text{H}$
 ${}^3\text{H} + {}^1\text{H} = {}^4\text{He}$
- Energy generated by fusion emitted at the surface as
 - radiation (50% IR, 40% VIS, 10% UV)
 - particles (solar wind)
- Surface temperature: 5.500 °C (white color)
- Emissions of energy fluctuating.

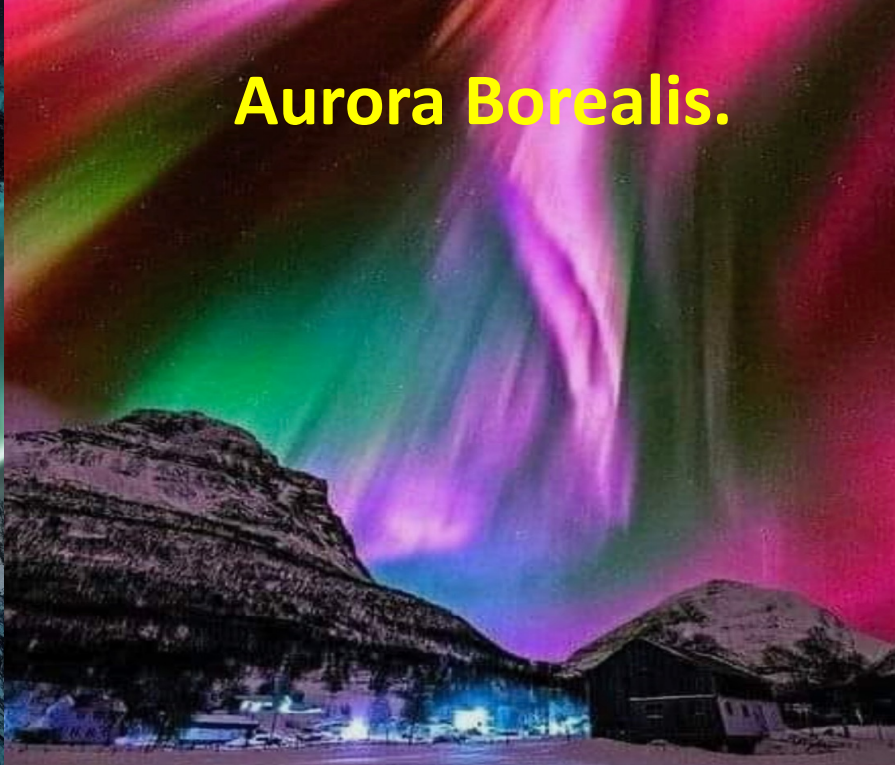


The turbulent surface of the Sun, its swirling corona and solar wind captured during a solar eclipse 2024
Source: ESA 2015



Aurora borealis

Aurora caused by solar wind entering the atmosphere of earth.
Earth magnetic field is protective but very strong solar particle streams can influence electrical fields on earth: 1980 power breakdown in Quebec.



A Short History of our Society.

Stefan Zweig (1881-1942):

„Wer die Vergangenheit nicht versteht,
versteht nichts wirklich.“



**Historia
magistra
est.**



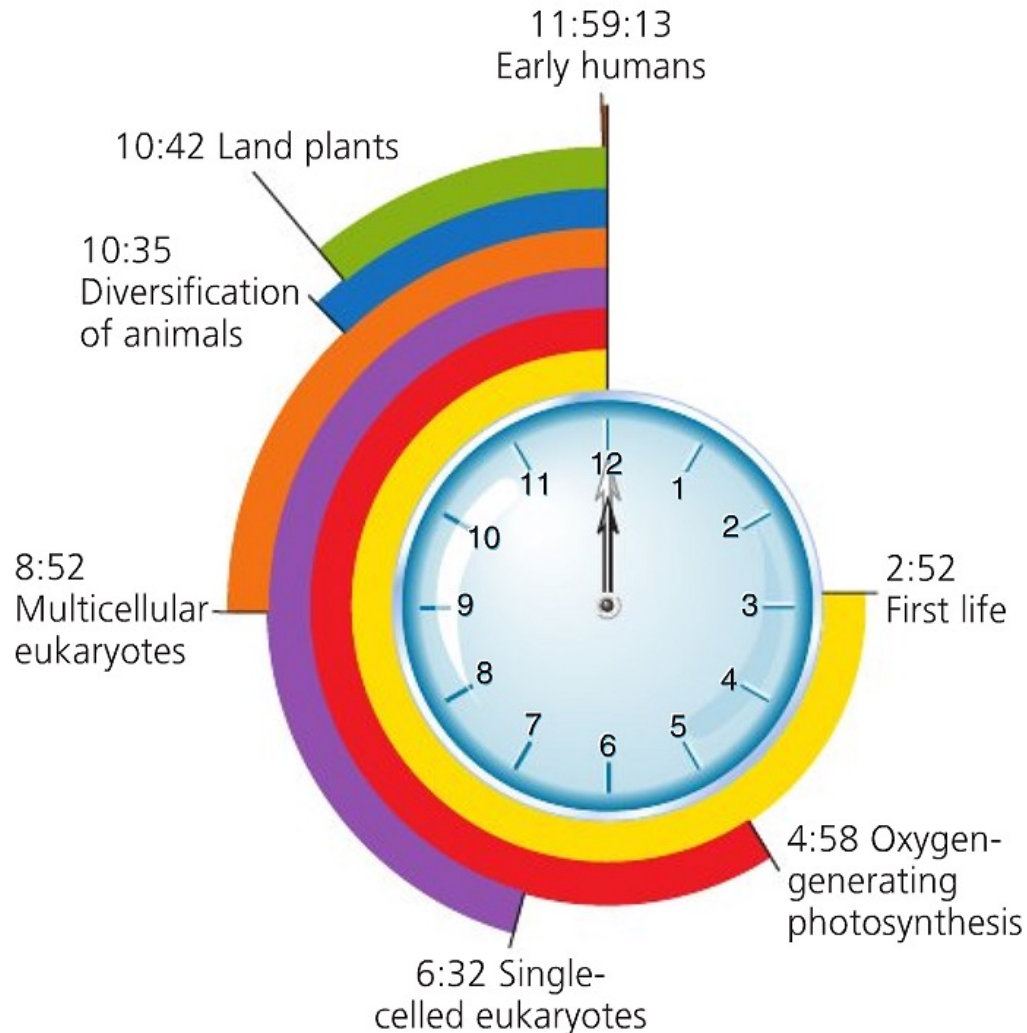
Sir Winston Churchill (1874-1965):

„Those who fail to learn from history
are condemned to repeat it.“

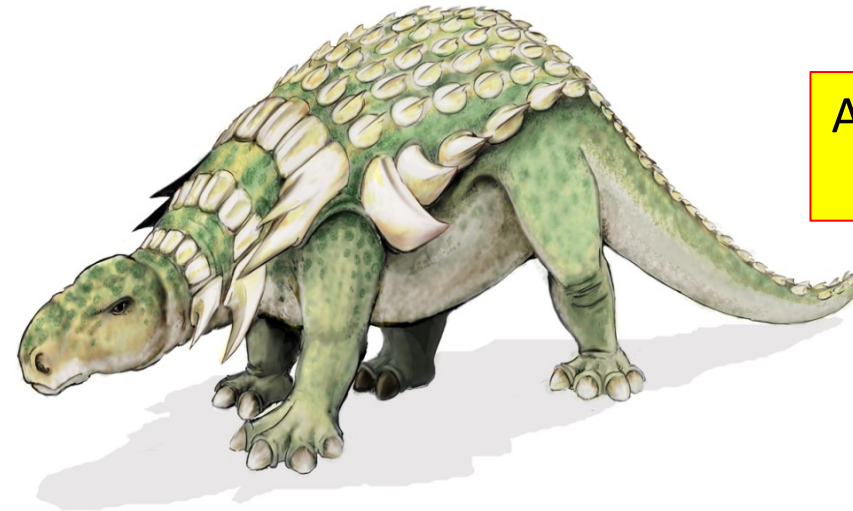
The Evolution of our Planet.

Looking back: The short history of the human development.

- Our planet was born about 5 billion years ago.



- During the ages many species developed: from procariotic and eucariotic cells to mighty animals.
- Many disappeared and gave space for new species.



Ankylosaurus
Edmontonia

- Humans arrived late as they are the most complex product of evolution.

Source: Withgott and Brennan: Environment, Pearson 2008

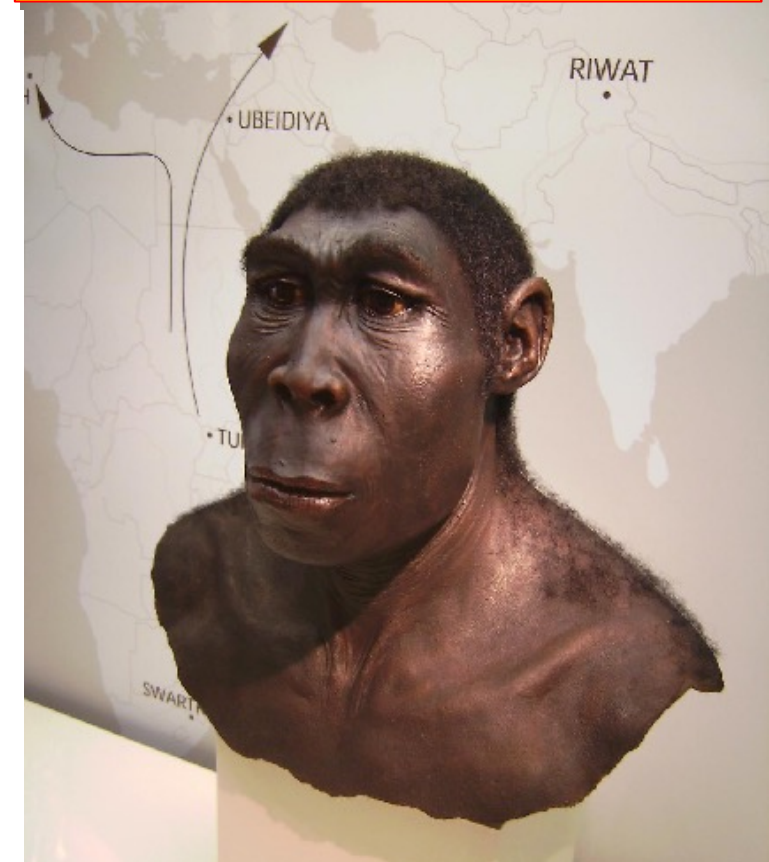
From Apes to Hominins.



Australopithecus, size 1,2 m,
lived 3 – 4 million years ago.

- ***Species Homininae:***
 - 6 – 10 million years ago separate evolution of hominins from the chimpanzees and gorillas.
 - Gradual development of bipedalism:
 - Detection of wild animals overlooking the grass in the African savannahs.
 - Development of hands and fingers gave new possibilities.
 - *Species Homininae* however lacked the large brains of modern humans.
- ***Homo erectus:***
 - Originally migrated from Africa 2 million years ago, and dispersed throughout most of the Old World, reaching as far as Southeast Asia.
 - *H. erectus* was the first to control fire.
 - Various species of *homo erectus* developed in different regions of the world.

Homo erectus. Height 1,80 m.



- *Homo yuanmouensis*
(1,7 mio years)
- *Homo pekinensis*
(400.000 years)
- *Homo neanderthalensis*
(300.000 years)

The Cognitive Revolution.

- ***Homo sapiens:***

- Seems to have developed some 200.000 years ago in Africa.
- Homo sapiens inhabited Eurasia and Oceania some 40.000 years ago, and the Americas some 10.000 years ago.
- The appearance of homo sapiens lead to the extinction of other homo species and many types of animals (large mammals like the mammoth).
- They hunted wild animals and gathered wild plants for food supply.
- *Homo sapiens* became the dominating species in nature.

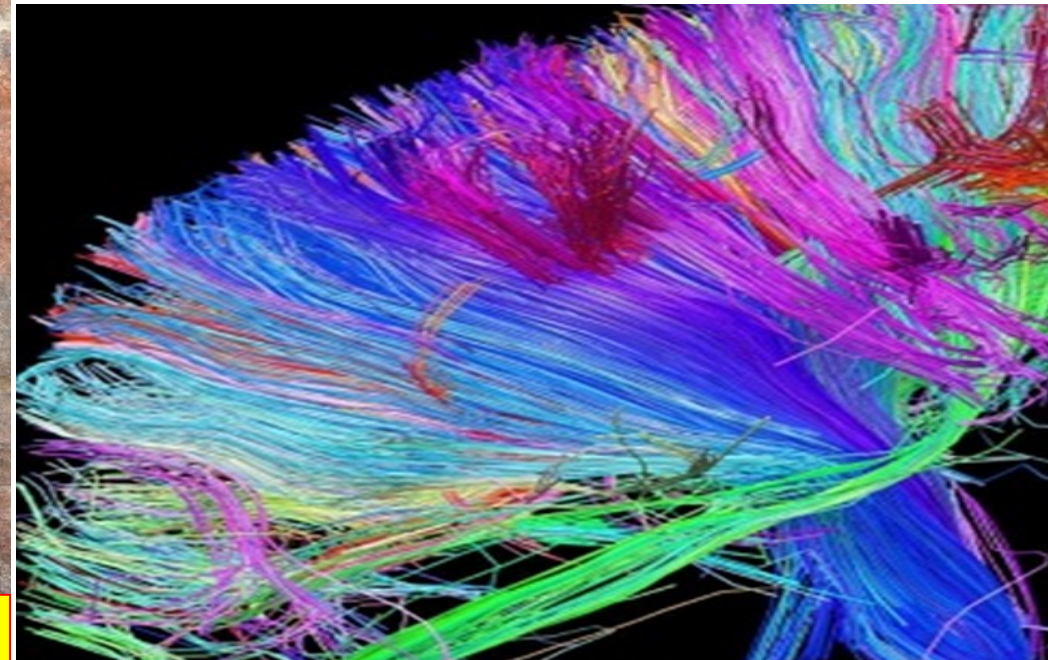


Cave painting of a hunter in Northern Australia.

99% of the 23.000 genes of humans are identical with those of the chimpanzees.

- **Difference: Size of the brain**

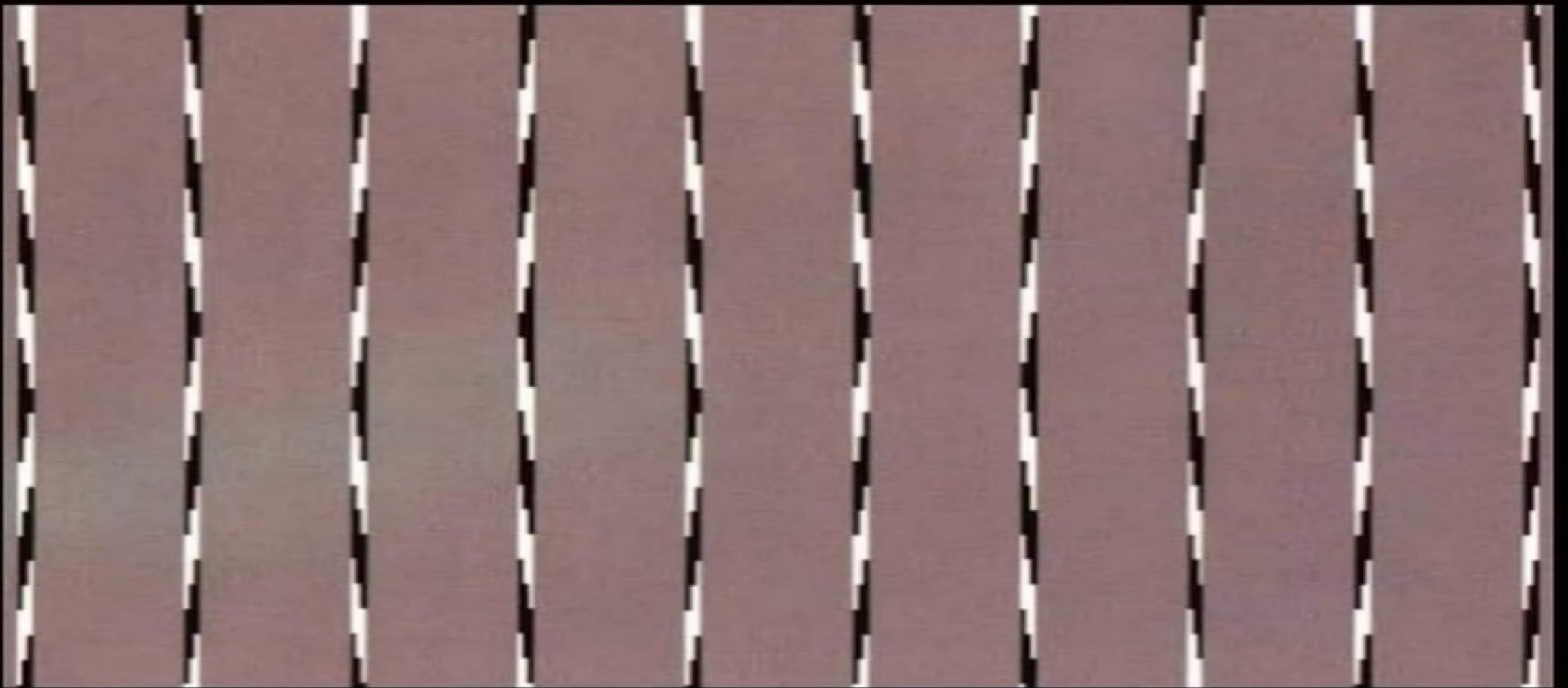
- Human brain has a weight of about 2 kg and is therefore 5 - 10x larger than that of other animals (in relation to body weight).
- Contains 100 billion cells connected in a complex 3-dimensional structure.
- Consumes 25% of the energy uptake.



Nerve cells in human brain.

The Human Brain – a Perfect Construction?

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Optical illusion all **Lines** are
Straight.

Source: Facebook 2024

The Migration of Homo Sapiens.



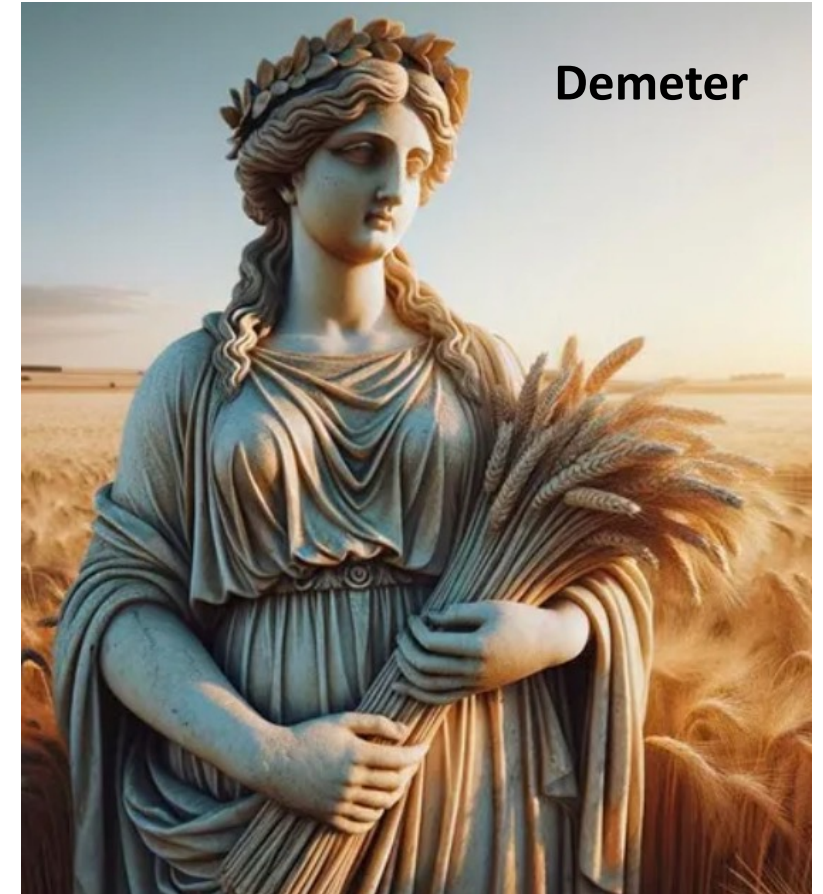
The early global migrations of Homo sapiens are one of the most remarkable movements in human history. Beginning with small groups venturing out of ancestral Africa, these early humans spread across continents, encountering diverse landscapes and adapting with incredible resilience.

The Agricultural Revolution.

- Until ca. 10,000 years ago most humans lived as hunter-gatherers in small egalitarian nomadic groups known as band societies.
- Then advent of agriculture led to permanent human settlements, the domestication of animals and the use of metal tools.



Early domestication: cow being milked in ancient Egypt.

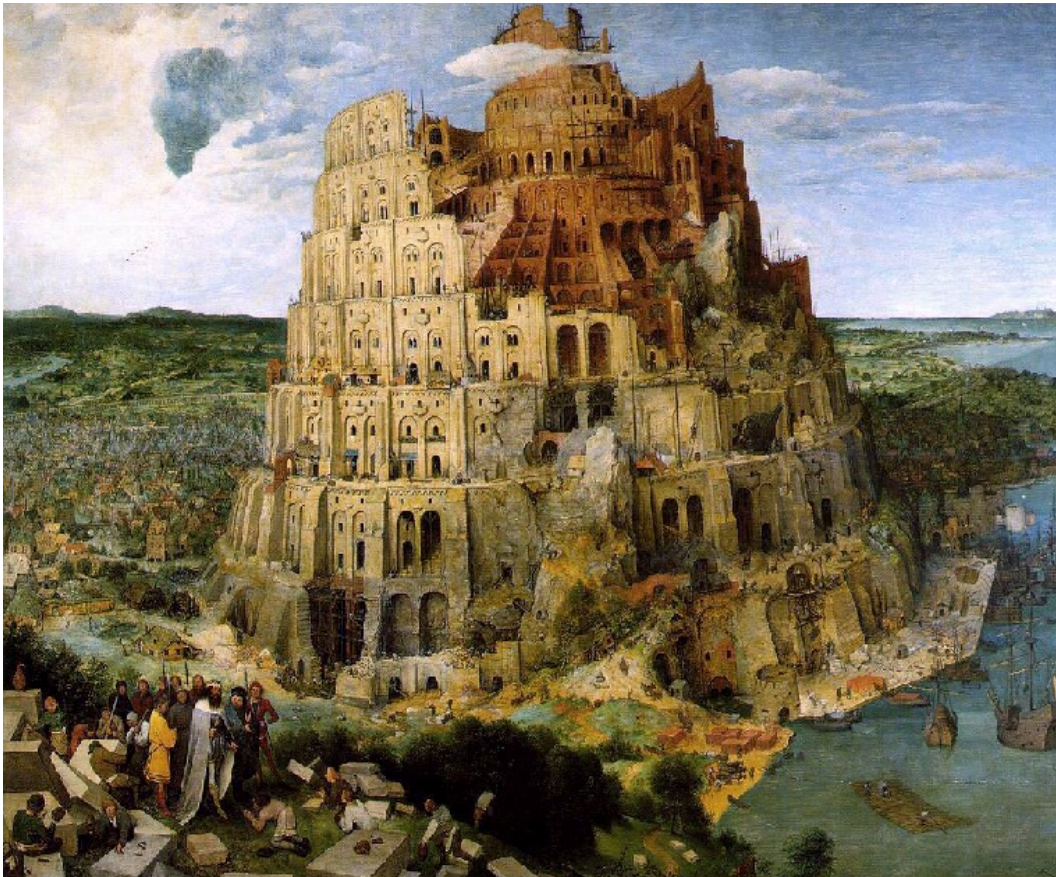


Demeter

Greek goddess for agriculture.

The Birth of Civilization.

- Agriculture encouraged trade and cooperation, and lead to a complex society, marking the begin of „civilization“.
- Consequently the first proto-states developed in Mesopotamia, Egypt and the Indus Valley about 6,000 years ago.
- Cities were built, military forces were formed for protection, and government bureaucracies for administration.
- States cooperated and competed for resources, often in long wars.



Tower of Babel by Pieter Bruegel de Oude.



The Trojan War (1.400 BC ?).
„Timeo Danaos et dona ferentes.“

Religions.

Some 3.000 to 4.000 years ago major and influential religions emerged.

Hinduism in South Asia.



Krishna (left), the eighth incarnation (avatar) of Vishnu, with Radha.

Judaism in the Middle East.



Prophet Abraham making his Treaty with God.

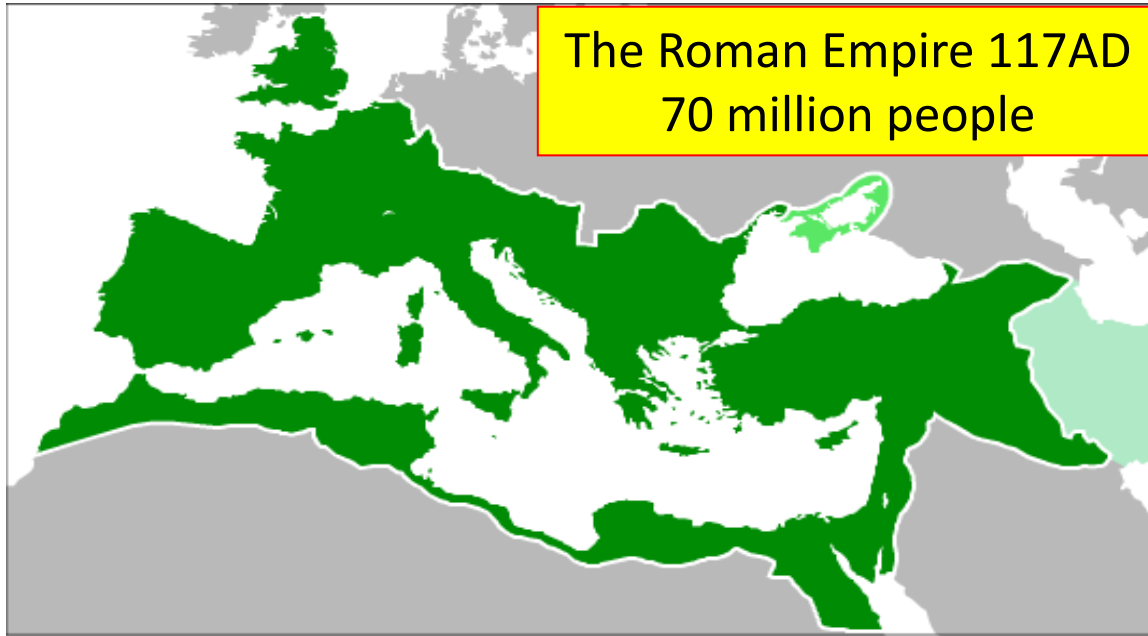
- This was followed later by another 3 major religions:
 - Buddhism in Asia around 550 BC.
 - Christianity originating in Judea around year zero.
 - Islam in the 7th century AD in Arabia.

These major religions have today 6 billion followers.

The Ancient Empires.



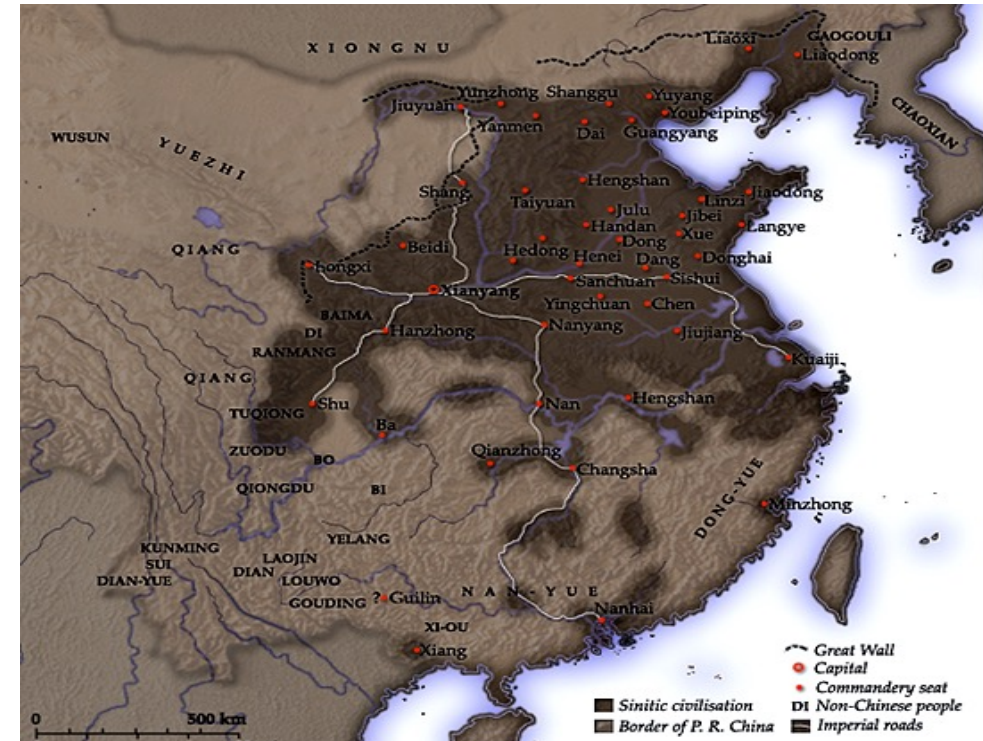
Persian-Median Empire 500BC – 50 million people



The Roman Empire 117AD
70 million people

- Around 2,000 – 3,000 years ago the first large empires were established through conquest of neighbor territories and populations:

- *Persian-Median Empire*
- *Qin Empire (China)*
- *Roman Empire*



Qin Empire 215BC - 20 million people

The Origin of Western Civilization.

- The foundations of the Western civilization were largely laid in the philosophical schools of Greece between 500 and 100 BC: ethics, concepts of states, principles of law, mathematics, geometry, astronomy...



The School of Athens founded by Plato in 385 BC (Raffaello Santi).

- The foundations of the governance systems of the Western world were developed in Rome from 500 BC till 500 AD.



A Roman aureus struck under Augustus AD 13–14

The Middle Ages.

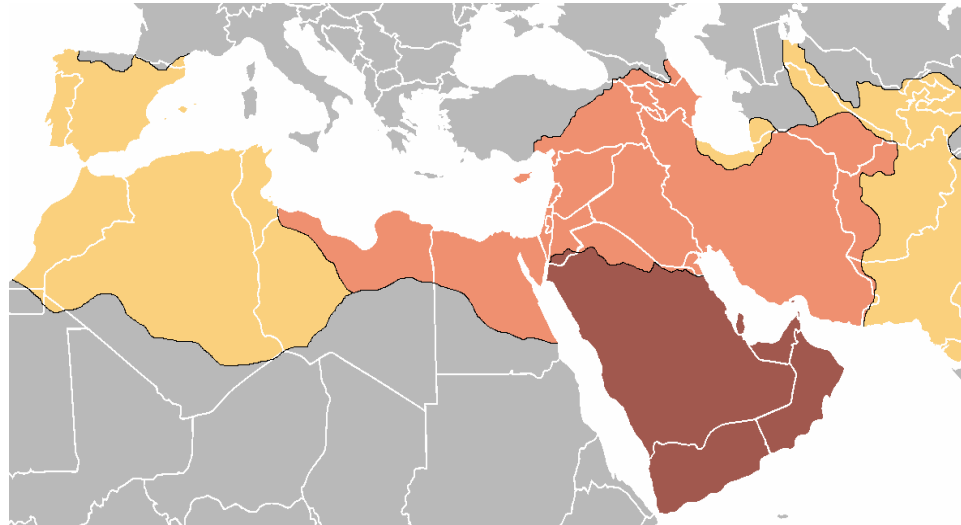
The Middle Ages saw the rise of revolutionary ideas and technologies.

—In China, an advanced and urbanized economy promoted fine arts and innovations such as printing and the compass.



A Chinese Tang Dynasty (618–907) sculpture Buddha.

—In the Mediterranean Region the Islamic Golden Age brought about major scientific advancements in the Muslim empires.



Islamic empire 800 AD.

Jabir Ibn Hayyan (721-815) introduced the experimental method to chemistry. He also established the chemical industry and perfumery industry.



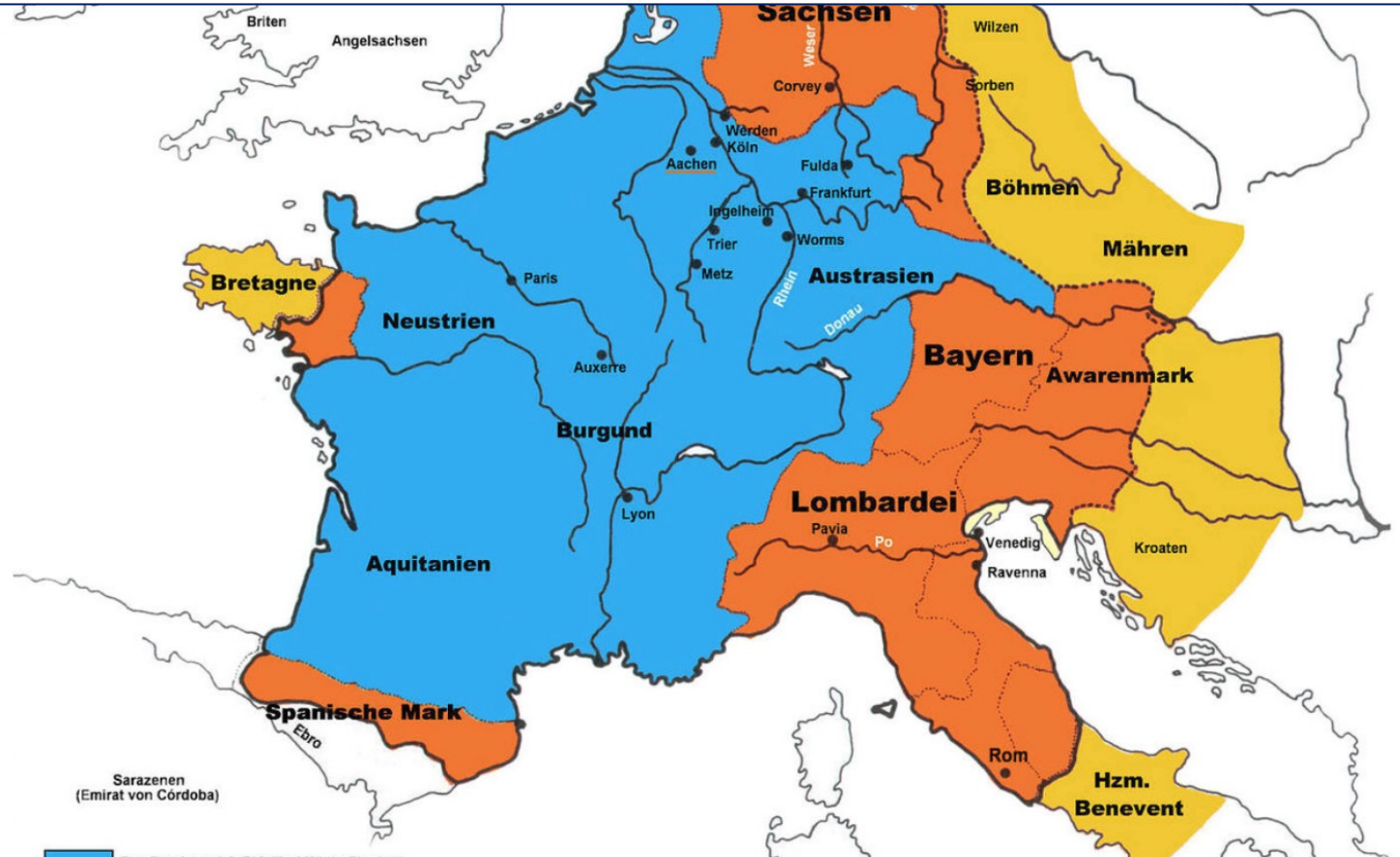
The Middle Ages.

In central Europe a new powerful Christian empire arose.



Carolus Magnus (748-814)
Pater Europae

Karl der Große, crowned by the Pope in Rome 800 AD, founded the Holy Roman Empire of German Nation.



This empire would form the core for the development of Central Europe driven by France and Germany.

The Middle Ages.

In Europe a new Christian civilisation developed which created the basis of our present society: communities, churches, castles and masterpieces of art.



Capella degli Scrovegni, Padova,
with frescos by Giotto (1267-1337)



Santa Maria Assunta, Siena, 13th/14th century.

The Middle Ages.

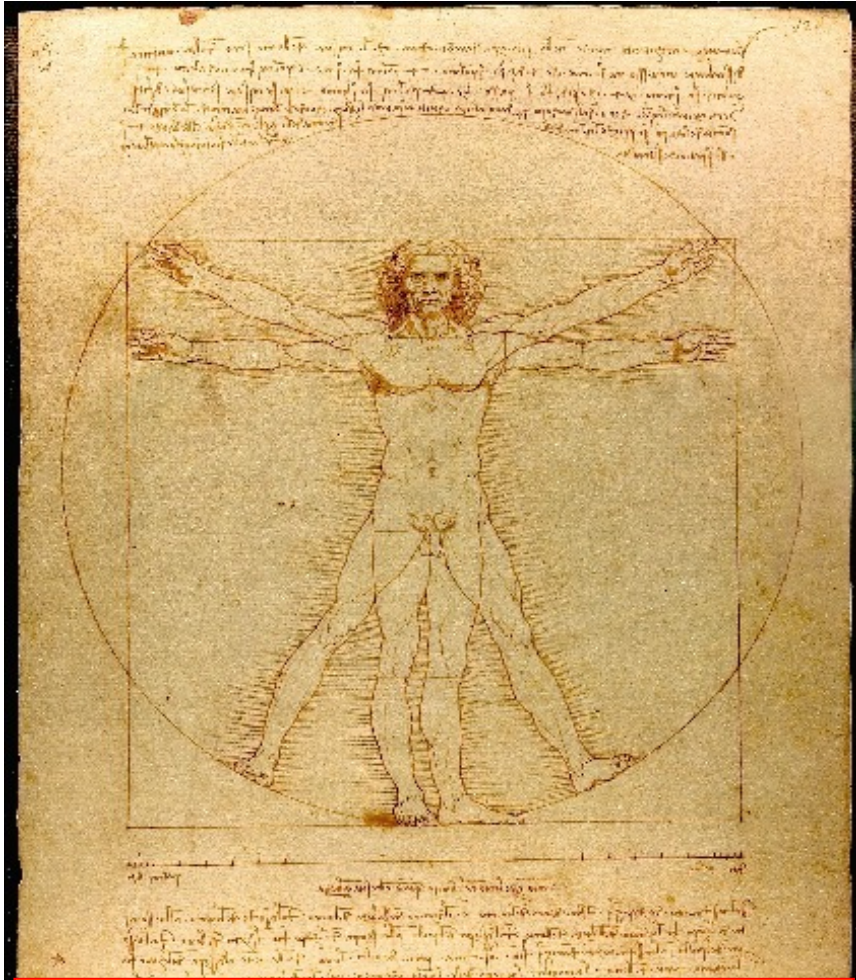
Also, a European “Civil Society” emerged with farmers, craftsmen, merchants, soldiers, administrators, clergymen, artists, traders and a cultivated landscape developed.



Unknown artist: Florence 1308

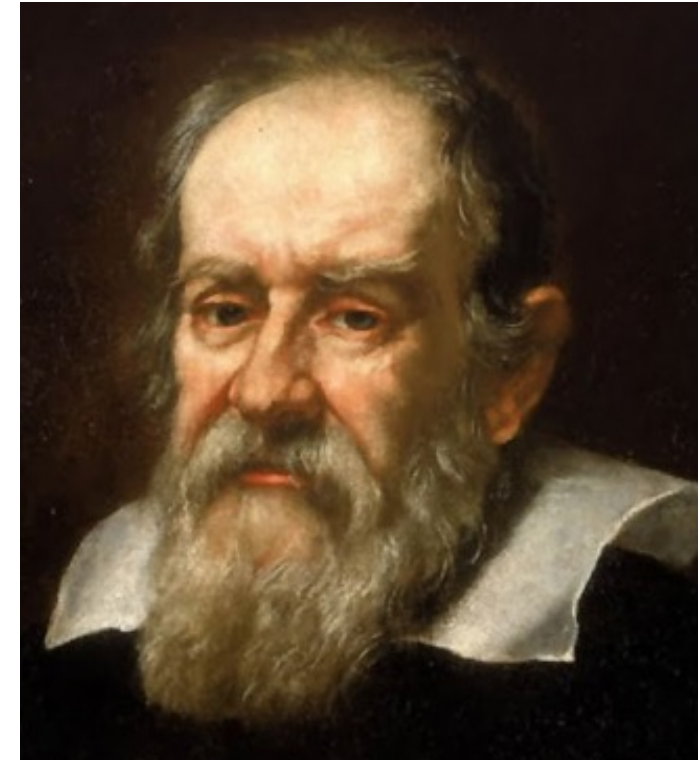
The Renaissance.

The rediscovery of classical learning led to the Renaissance in the 14th/15th century.



Leonardo da Vinci's Vitruvian Man of perfect proportions.

- Revolutionary scientific discoveries and inventions would provide the basis for a rapid development of a modern society:
 - Heliocentric system (Galileo Galilei, Nikolaus Kopernikus)
 - Universal Laws of Mechanics (Isaac Newton)
 - Wave theory of light (Christian Huygens)
 - Printing press (Johannes von Gutenberg)
 - Compass (Flavio Goia)
 - Mechanical clock (Peter Henlein)



Galileo Galilei (1564 – 1642)

• This „Golden Age“ of Europe produced also the most admired paintings, sculptures, architectural monuments.

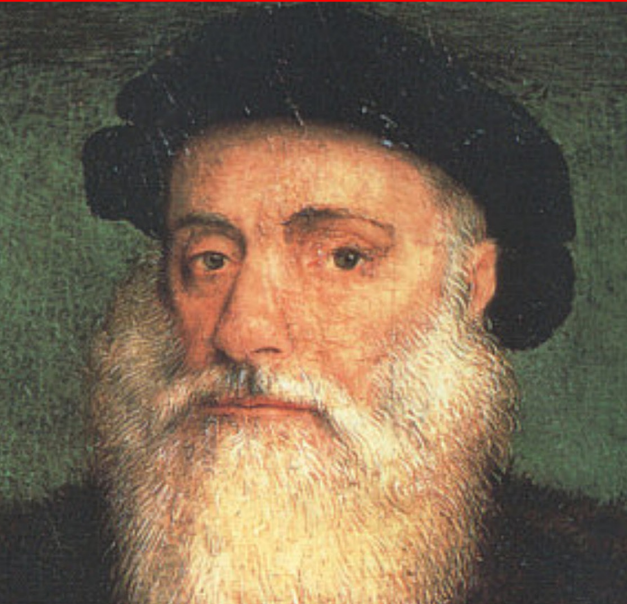
The Age of Discoveries.

Over the next 300 years, European seafarers set out to explore the unknown world and discover new countries and continents:

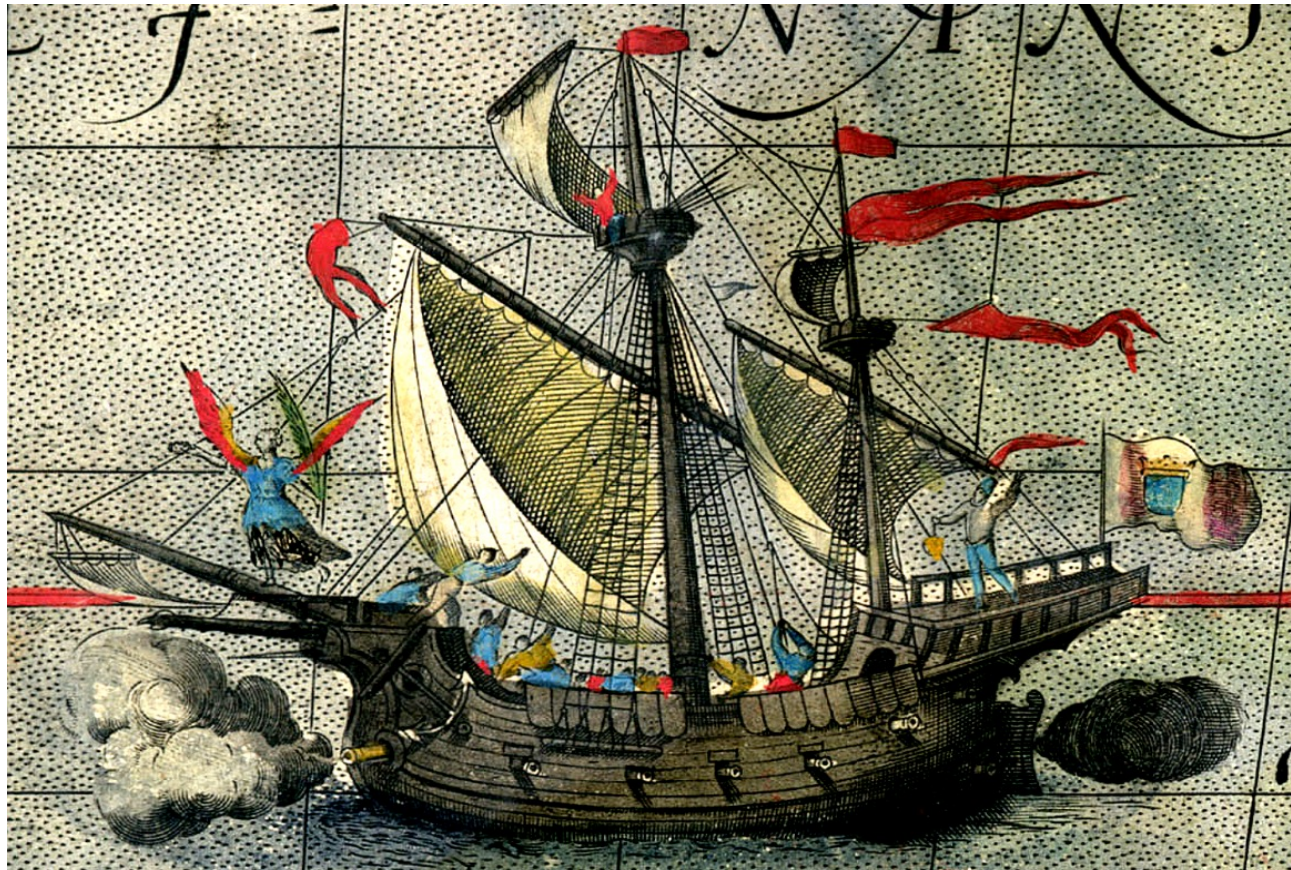
America, South Africa, India, Southeast Asia, Australia



Cristoforo Colombo
(1451-1506)



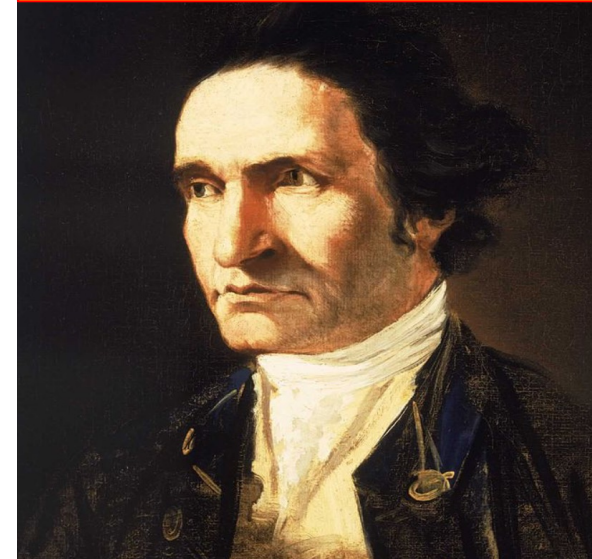
Vasco da Gama (1469-1524)



Victoria – only ship to return from Magalhães expedition.



Fernão de Magalhães
(1480-1521)



James Cook (1728-1779)

Colonization.

- Exploration and imperialistic conquest brought much of the Americas, Asia, and Africa under European control.
- First colony: the Aztec empire became New Spain.



Quetzal feathered headdress, Mexico (Weltmuseum Wien)



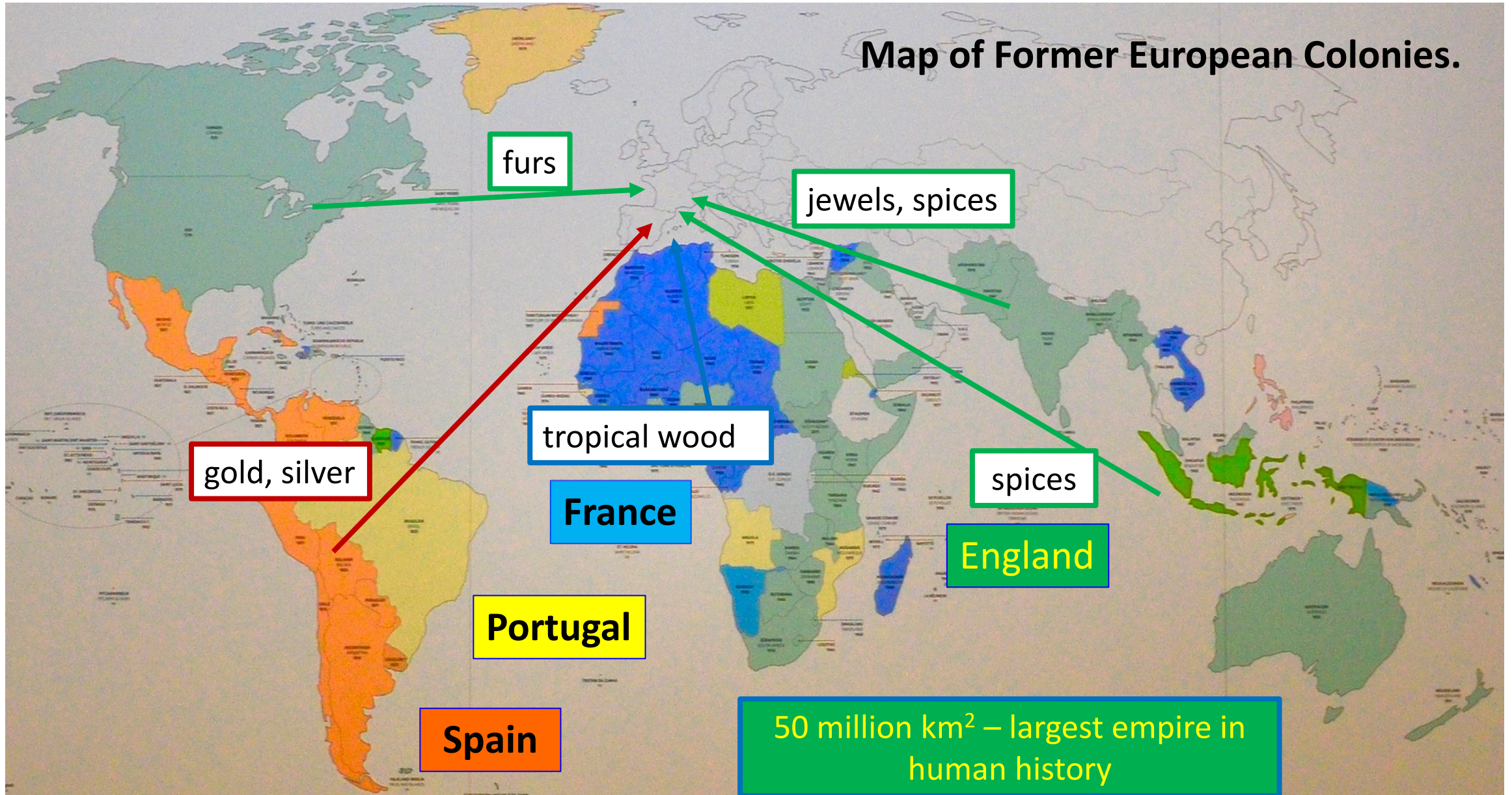
Hernando Cortes (1485-1547)

Conquest of the Aztec Empire:

500 soldiers with horses and firearms defeated an Aztec army of more than 50.000 with the help of an uprising of other peoples suppressed by the Aztec rulers.

„Masters of the Universe“.

Map of Former European Colonies.



„Britania rule the waves!“

- Huge and powerful trading companies were formed for the exploitation of the new colonies:
- The **East India Company** (1600–1874) was an English enterprise formed to trade in the Indian Ocean from India to Southeast Asia.



- 200 ships.
- 50.000 employees.
- Half of the world's trade 1750-1850:
 - Mainly cotton, silk, indigo, dye, sugar, species, tea, opium.
- *De facto* rulers of the Indian subcontinent till 1857.



Company flag (1801)



Coat of arms (1698)

The Age of Enlightenment.

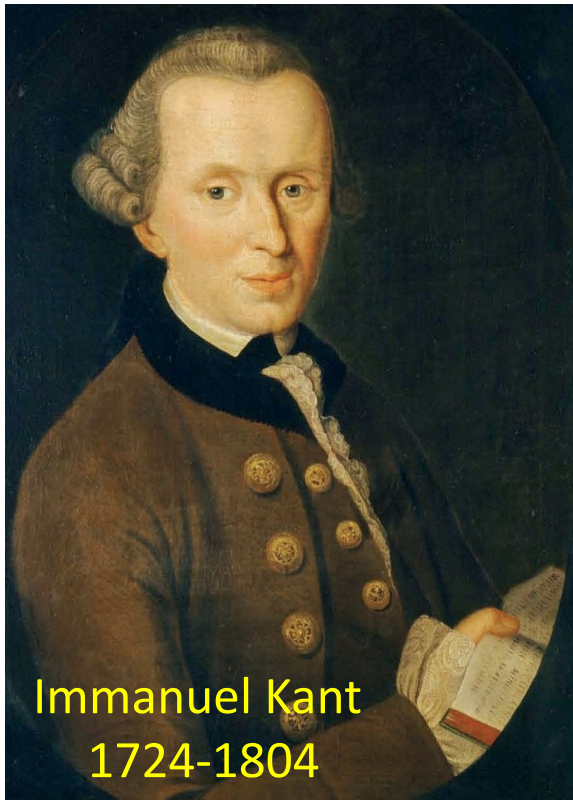
Charles-Louis Baron de Montesquieu:

De l'Esprit de Loi (1748) –

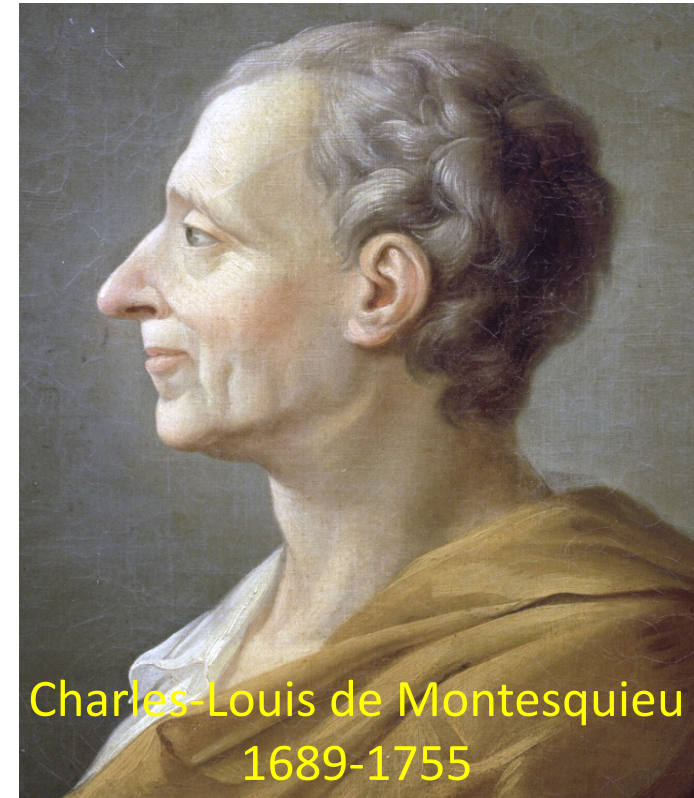
Principle of the separation of powers
(legislation, executive, jurisdiction).

Immanuel Kant: „*Sapere Audere*“ (1784) -

“Dare to know, Dare to think for yourself.”



Immanuel Kant
1724-1804



Charles-Louis de Montesquieu
1689-1755



French Revolution 1789:
Liberté, Fraternité,
Égalité.

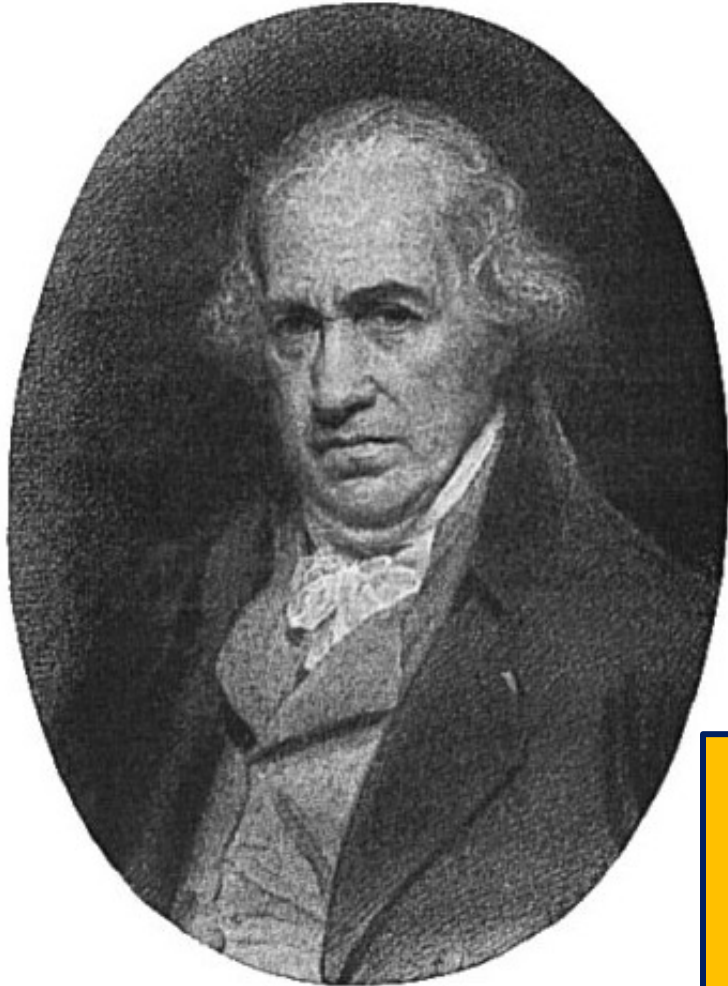


Europe is the only region in
the world, where such a
radical change of thinking
occured.

Provides the basis of our
liberal and free societies.
USA implemented these
ideas in its constitution 1789.

The First Industrial Revolution.

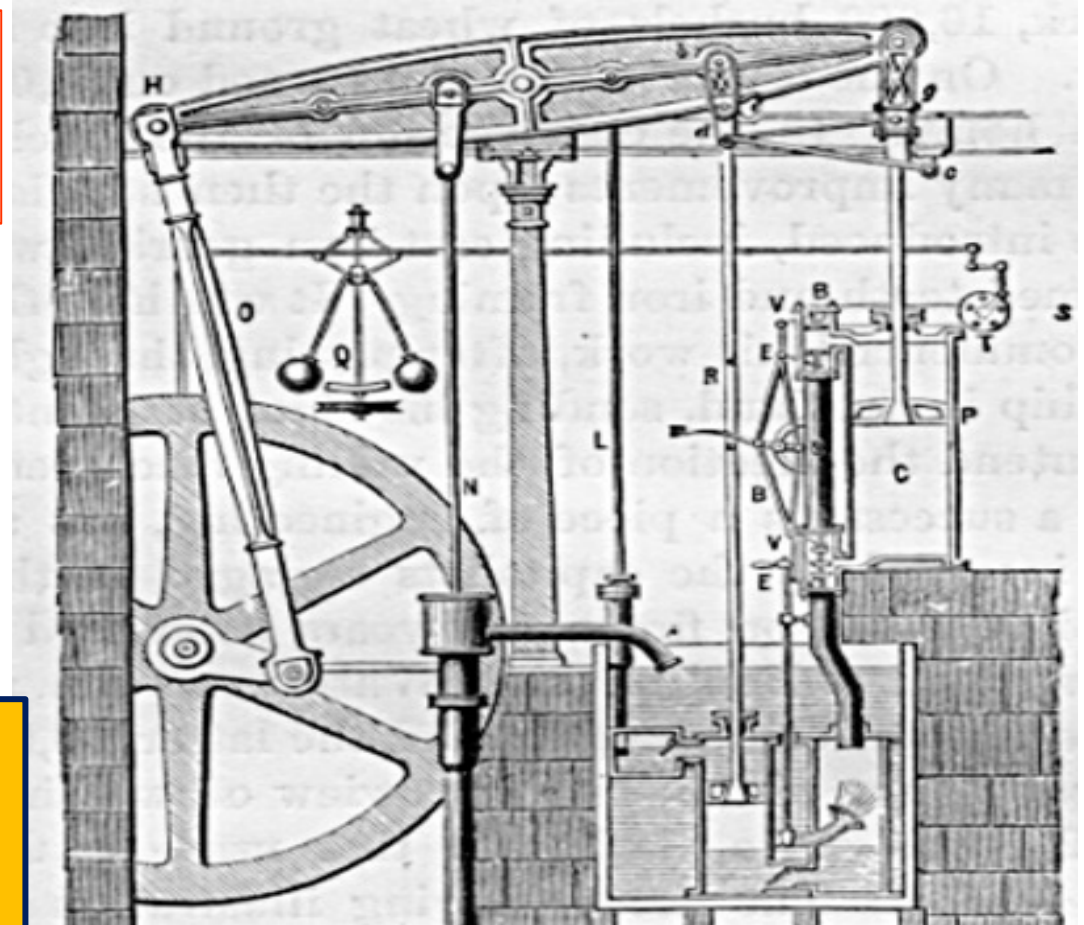
- The First Industrial Revolution from 1750 till 1850 promoted major innovations: steam engine to introduce mechanical labor, mechanical transport, such as the railway and steam ships.
- Energy produced by burning of carbon to CO_2 : charcoal, brown and black coal.



Steam engine designed
by Boulton & Watt.
Drawing from 1784.

James Watt,
born Greenock,
Scotland 1736,
died Handsworth,
England 1819

***One of the most important
inventions in human history:
Replaced human labor by
mechanical energy.***



The Rise of Chemistry.

Antoine Lavoisier (1743 – 1794)

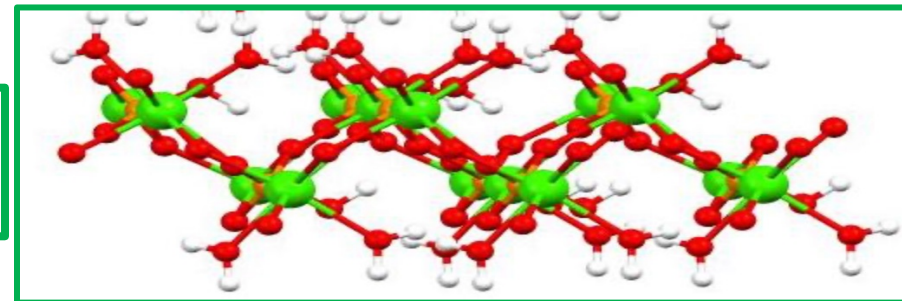


- Development of chemical sciences provided the basis for new materials, new medicines, new forms of energy production, a better understanding of nature and its processes and thus improved food production.

- Discovery of the role of nutrients for plant growth and development of the first chemical fertilizer allowed to combat hunger and starvation in a rapidly growing population.

Superphosphate – the first chemical fertilizer.

Justus von Liebig (1803 – 1873)



The Second Industrial Revolution.

•The second industrial revolution from 1850 till 1940 brought about major innovations, like:

- modern steel production → railways
- electricity → radio, electric lightening, telephone
- combustion engine → automobiles
- pharmaceuticals → modern medicine



European railway network 1850



Syphilis caused by bakterium treponema pallidum treated with Arsphenamin (1910).

In the 19th Century Europe had become the most glorious part of the world.

World exhibition London 1851



London 1851: Crystal Palace 560x137m

Paris 1889



Tour Eiffel Paris 1889: Height 330m

Two large empires in the Center of Europe.

A rising nationalism caused massive tensions between European nations.

- **The Austro-Hungarian Empire:**

- 674.000 km², 53 million people, 17 different nations.
- Severe tensions between Austrians, Hungarians, Czechs, Italians.



- **The German Empire (Deutsches Reich) founded 1871.**

- 540.000 km², 64 million people, mainly Germans.
- Massive armament to become a global player.



Another large empire in Eastern Europe.

An absolute monarchy with a very rich nobility and an extremely poor population:
Tsarist Russia moving towards a revolution.



Marc Chagall, „Witebsk“ (1911).

At the peak of this evolution Europe decided to go to war.



Albin Egger-Lienz: "Soldaten" (1915).

From 1914 till 1945 Europe finally lost everything in 2 huge wars.

World War One:

Cause was mutual distrust between
England, Russia, France, Germany, Austria.

20 million dead

Follow-up: Bolshewik/Stalinistik revolution in Russia.

30 million dead

Global financial crash in 1929, widespread poverty and
unemployment in Europe.

Rise of fascism.

World War Two:

Cause was aggression by the Nazis (Hitler) supported by
Italian fascists (Mussolini).

50 million dead

Central Europe largely destroyed.
Millions of refugees.



The „Master of the Universe“ shrank to a
group of small states with little influence.

The Rise of a New Superpower.



Iwo Jima, February 23, 1945
Raising the first flag.

- The USA was the winner in the two World Wars.
- Massive shift of political power from Europe to America.
- USA have become
 - the largest industrial nation in the world,
 - the technological leader,
 - the military superpower,
 - the cultural leader,
 - the global political leader, and
 - the dominating economic and financial power.



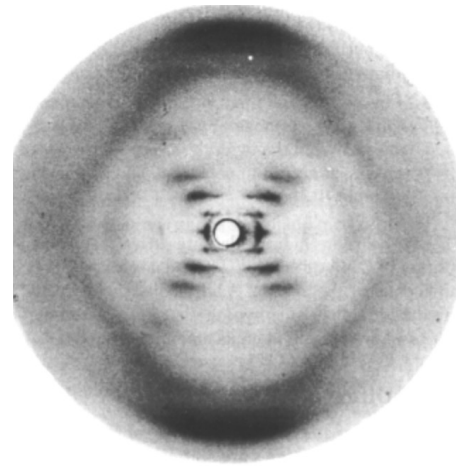
„In my empire the sun never sets“
(Charles V, King of the Holy Roman-German Empire 1500-1558)

The Third Industrial Revolution

- The second half of the the 20th century is characterised by new revolutionary scientific achievements, like the invention of the transistor, or the clarification of the structure of the DNA, leading to the Third Industrial Revolution.



First transistor invented by William Shockley, John Bardeen and Walter Brattain at Bell Labs December 23, 1947.



X-Ray diffraction pattern by Rosalind Franklin



Structure of DNA as discovered by James Watson, Francis Crick and Rosalind Franklin 1953 at Cambridge, UK.

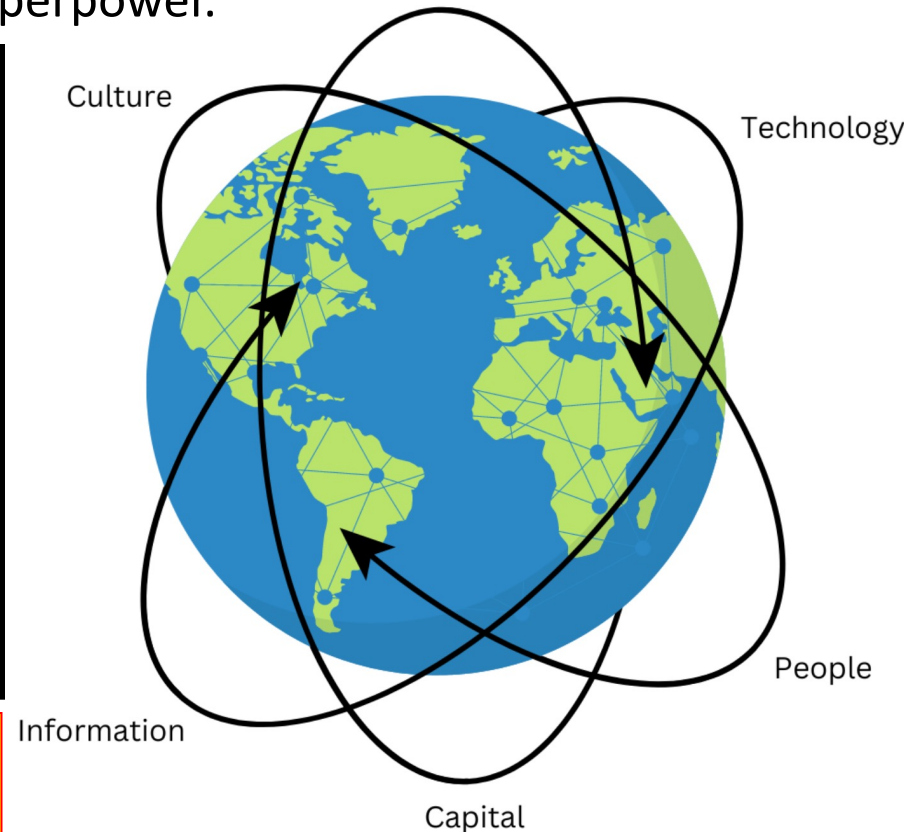
A New World: Restructuring and Globalisation.

- The second half of the 20th century was the period of restructuring:

- Emergence of many new states from former colonies.
- Expansion of the democratic political systems.
- Creation of the European Union.
- Rising of the USA to the global superpower.



Robert Schuman (1886 - 1963)
was one of the founders of the
European Union.



WTO agreement covers 95% of the world.

- The 21st century will be the period of globalisation.

- The most important basis is the WTO agreement of 1995 which provides for free movement of goods, capital, technology.

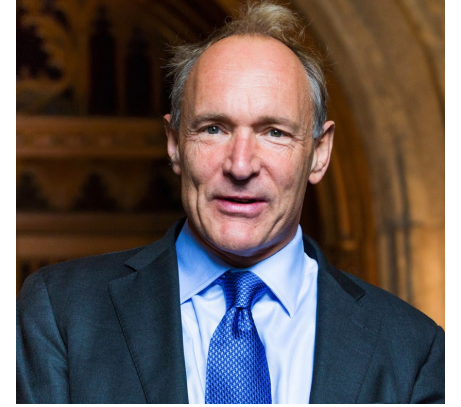
- The prime drivers for globalisation were/are

- the USA, Europe and Japan, who were looking for new markets for their industrial and service products, and
- the dynamic developing countries of Asia, like China, India, who provide these markets and act as producers for basic goods.

- **Globalisation poses huge challenges for the human society.**

The ICT Revolution: Towards the „Global Village“

- Globalisation means transcending classical geographical boundaries.
- ICT has largely impacted on individuals and societies across the globe.



- Tim Berners-Lee, a British scientist at CERN, invented the World Wide Web (WWW) in 1989.
- 5,5 billion internet users in 2024 (40 million 20 years ago)
 - 7 billion smartphones
 - 3 billion Facebook users
- Today 8 billion people from 1.000 nations and 200 countries interact, many of them in real-time.

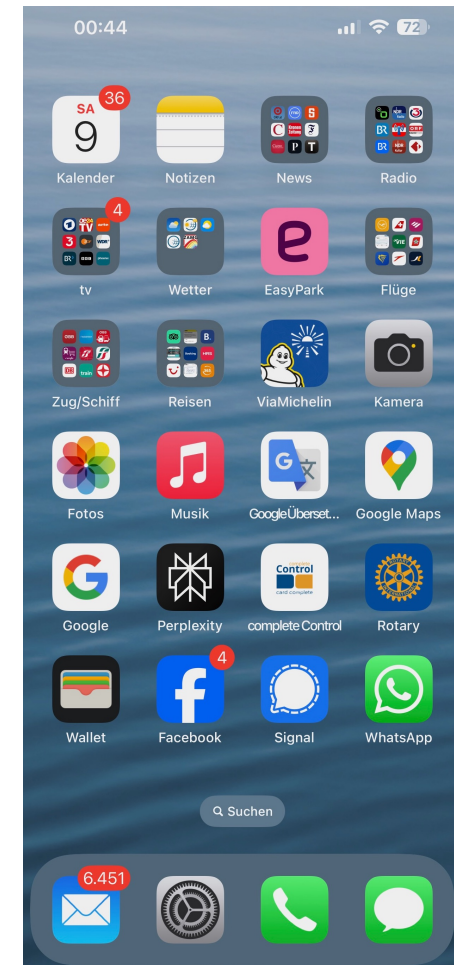
Globalization of Industrial Production.

The iPhone Success Story: "Designed in California, Assembled in China".

Headquarters Cupertino, CA, USA, 12.000 staff; total Apple staff 160.000.

Gross Profit of Apple 170 billion \$, expenditure R&D 30 billion \$ (2023).

Value of Apple: 3.000 billion \$ (2023)



2023: Apple
market leader
240 million

2007:
Nokia
market
leader
60 million

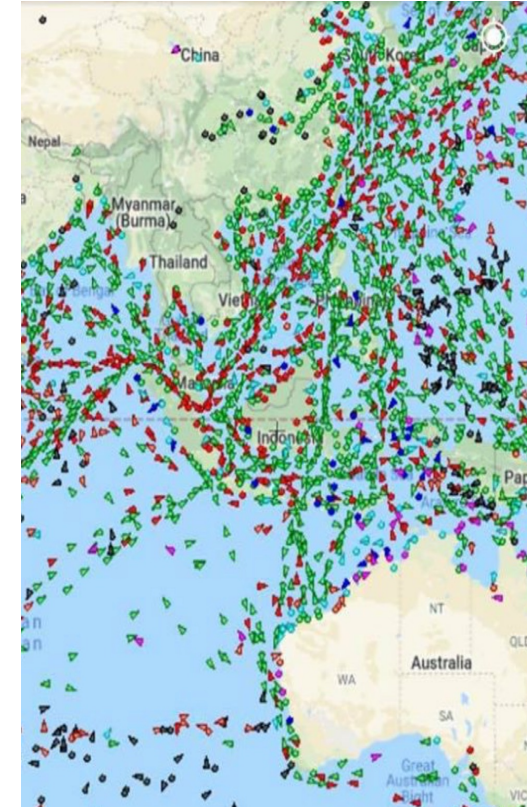
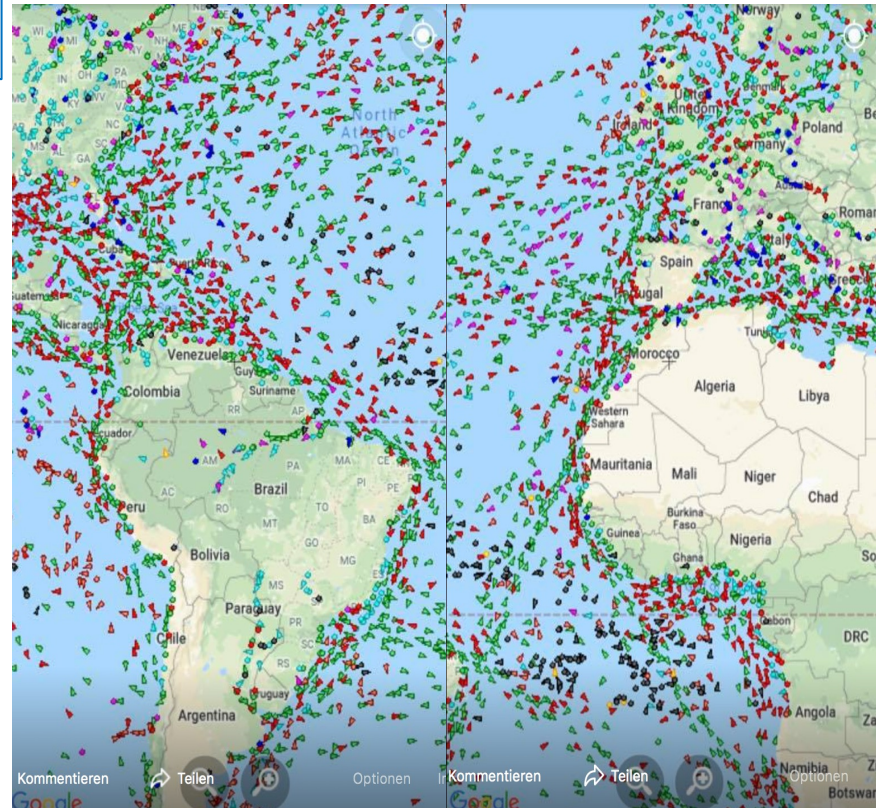
Global Mobility and Trade.

- **Air traffic:**
 - 26.000 air planes.
 - 40 million flights per year.
 - 9,4 billion passenger flights (2023).
 - Expected increase by a factor of 3 - 5 till 2050.

Snapshot taken in January 2024:
17.000 planes in the air at the same time.



- **Maritime shipping: 90% of global trade of goods**
 - 60.000 cargo ships (incl. 20.000 oil tankers).
 - 20 million containers in use.
 - 11 billion tons transported annually.
 - Value 25% of global GDP (17.000 billion \$).
 - Expected increase 100% by 2050.



Political Globalization.

- Globalization has a major economic and political impact – and is irreversible.
- 21st century will see emergence of new powers and the development of a very different „multicultural“ global economic and political system.



By 2050 the now dominating triad* US-EU-Japan will be replaced by the triad China-India-USA.

**Triad stands for the group of the 3 leading economic regions.*

“From the Transatlantic Age to the Pacific Age.”

The unilateral dominant position of the USA will come to an end.

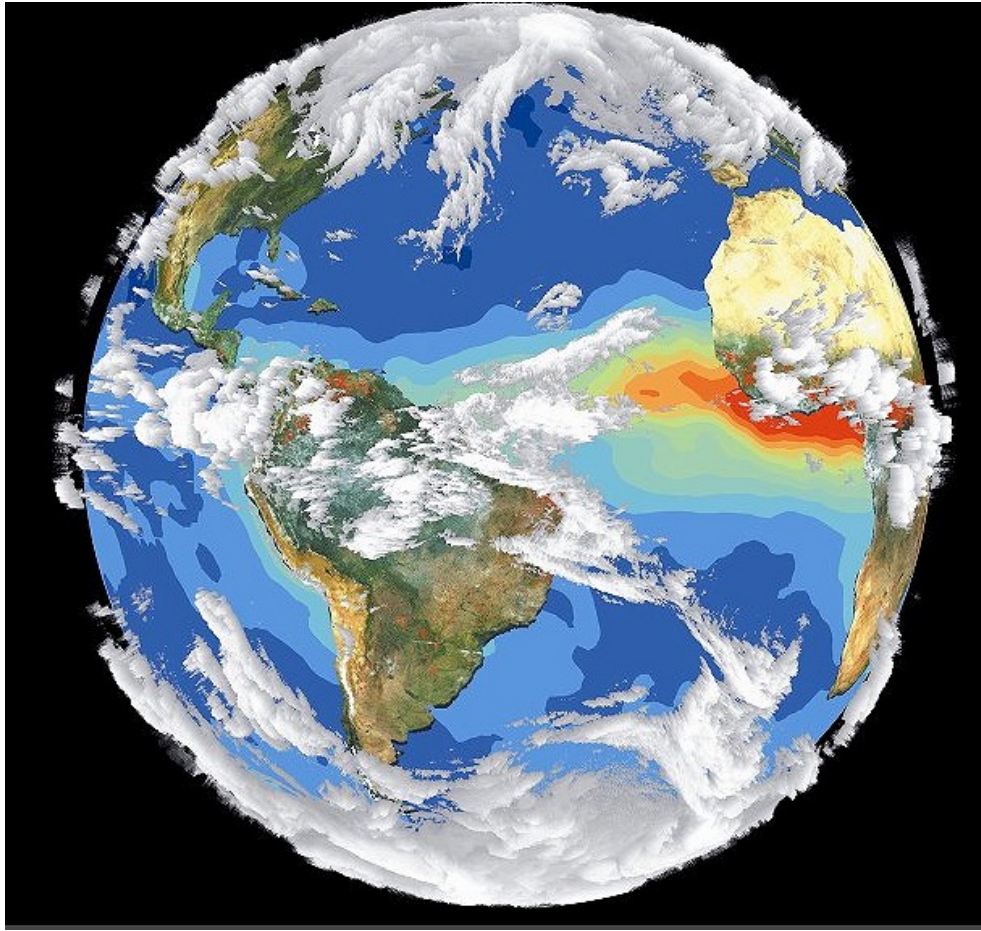
Multipolar world or dual hegemonial system lead by USA/EU/Japan and China/Russia?

Power constellation in the 21st century.

Source: Le Monde Diplomatique 2007

The Short History of the Human Development: The Anthropocene.

Human impact on planet Earth:



Source: NASA, NOAA, ESA-Meteosat, JAXA

- Transformation of half of the earth's surface.
- 10 fold increase in population during last 3 centuries.
- 15 fold increase in energy and resource consumption during last century.

Source: Facebook 2024



Mountaineers climbing the Mount Everest (8.848 m).



Icon of the Seas:
5.600 passengers