

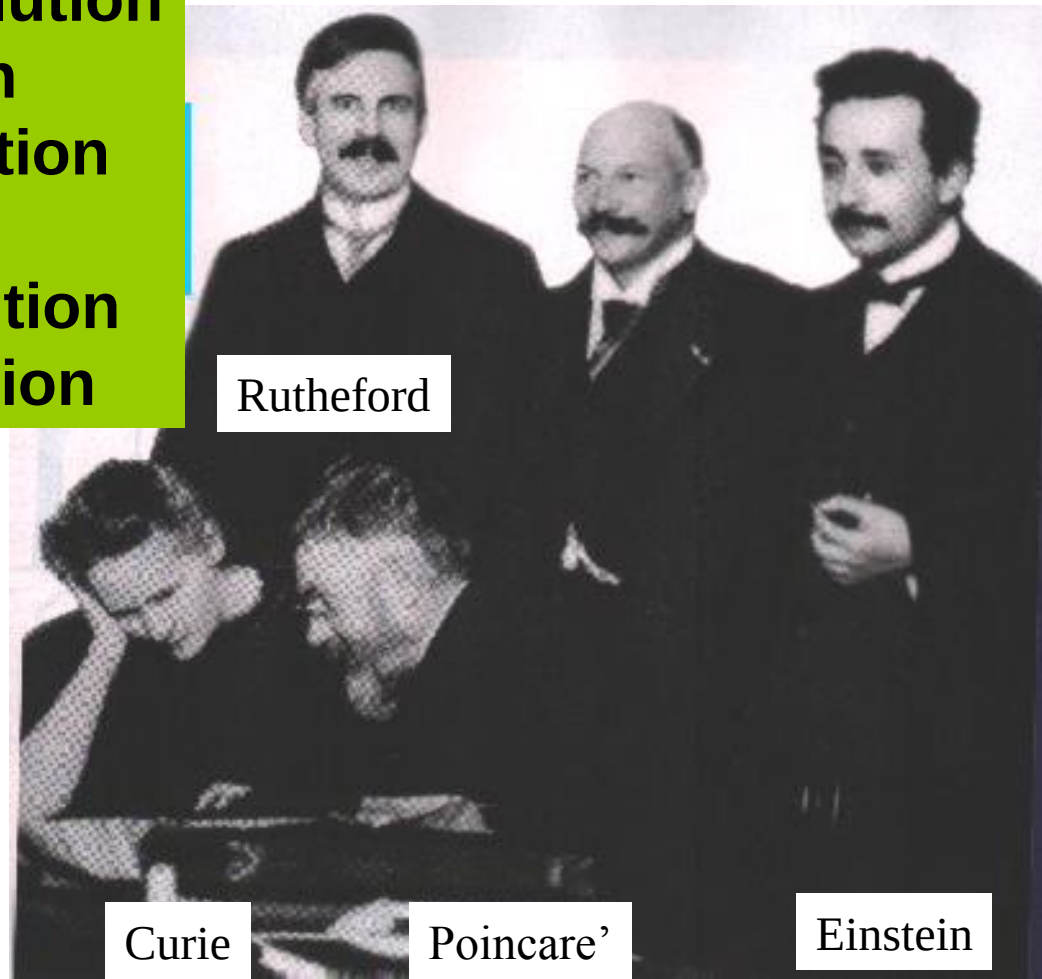
Logos 6: 31 May 2006
The Second Scientific and Industrial Revolution
Piero Scaruffi
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Logos 6: 31 May 2006

The Second Scientific and Industrial Revolution

The Electrical Revolution
The Transport Revolution
The Thermodynamic revolution
The Subatomic Revolution
The Cosmological Revolution
The Biological Revolution
The Psychological Revolution
The Mathematical Revolution



Rutheford

Curie

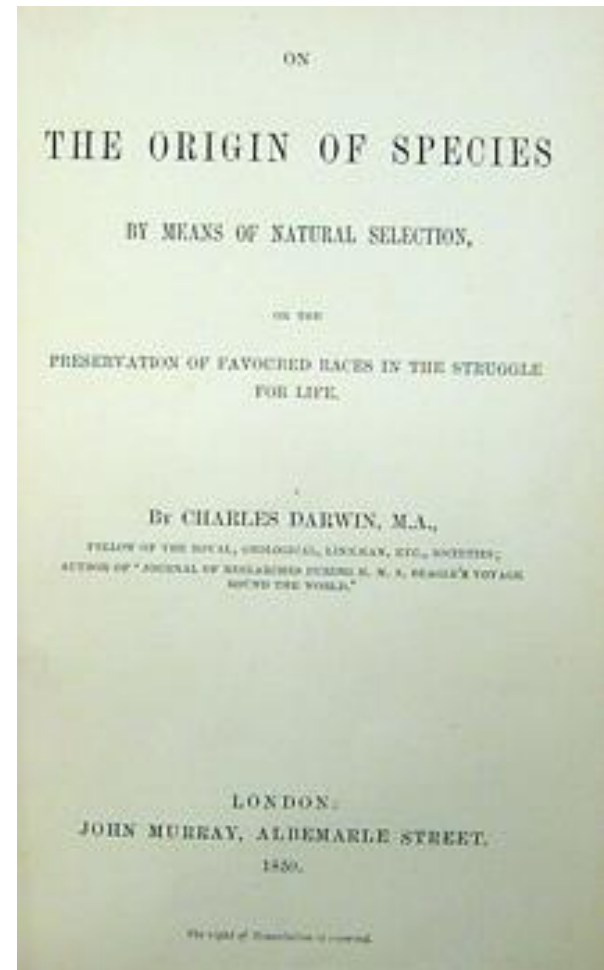
Poincare'

Einstein

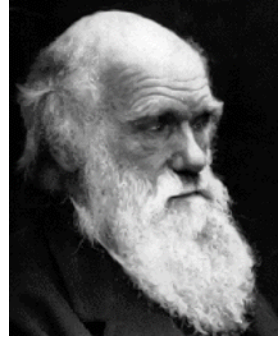
Bibliography

- **John Steele Gordon: “An Empire Of Wealth” (2004)**
- **Gerard Piel: The Age Of Science (2001)**
- **Peter Watson: The Modern Mind (2000)**
- **Roger Penrose:The Emperor's New Mind (1989)**

The Biological Revolution



The Biological Revolution



- **Charles Darwin (1859)**
 - **Animals evolved**
 - **Evolution=variation+selection**
 - **Adaptation**
 - **Struggle for survival**
 - **Adam Smith's economics transferred to nature**
 - **Design without a designer**

The Biological Revolution

- **Charles Darwin (1859)**
 - **Natural selection AND Sexual selection
(competition for survival AND competition for reproduction)**
 - **Sexual selection: males compete for females,
females choose males**

The Biological Revolution

- **Gregor Mendel (1865)**
 - **Phenotype vs genotype**
 - **Units of transmission of traits**

The Biological Revolution

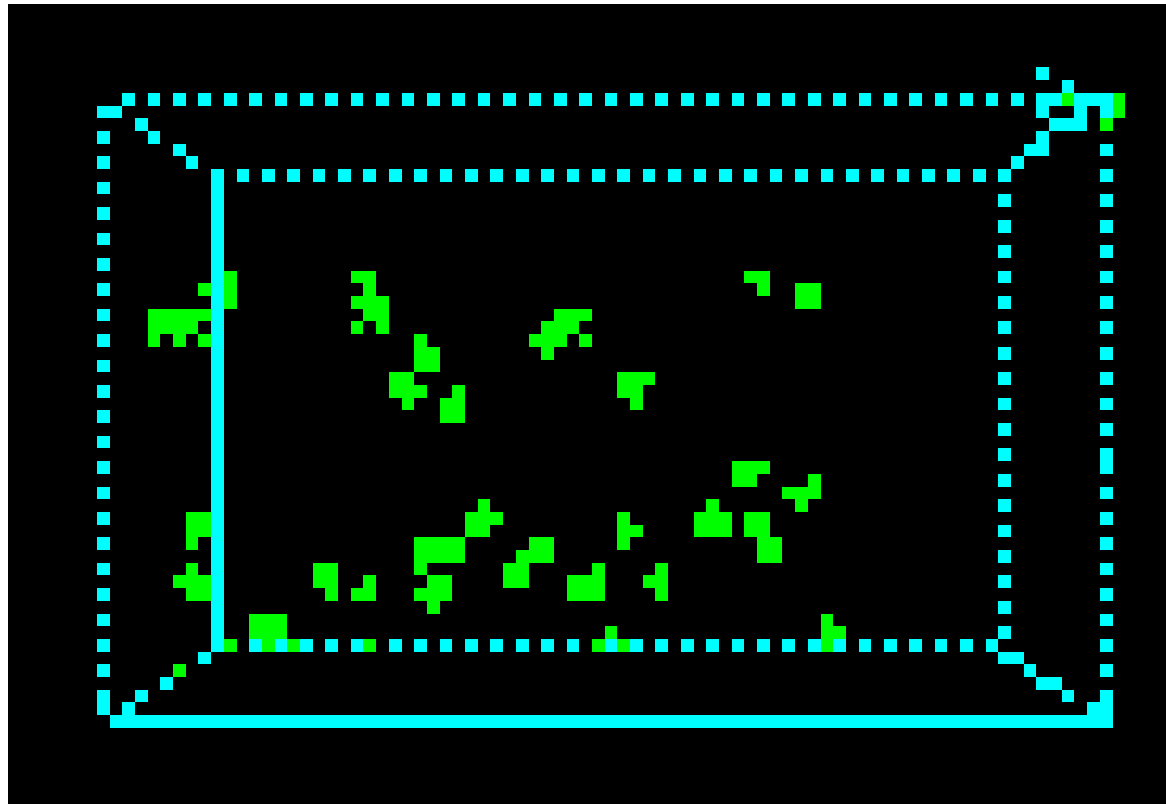
Germs

- **Louis Pasteur (1865): diseases are caused by germs**
- **Robert Koch (1875): anthrax**
- **Robert Koch (1882): tuberculosis**
- **Robert Koch (1882): cholera**
- **Paul Ehrlich (1909): syphilis**

The Biological Revolution

- **Biology**
 - **1859: Charles Darwin (Evolution=variation+selection)**
 - **1865: Gregor Mendel (Units of transmission of traits)**
 - **1906: William Bateson ("Genetics")**
 - **1920s: Thomas Hunt Morgan ("chromosomes")**
 - **1920s: Population Genetics (Probabilities)**
 - **1940s: Modern Synthesis (variation=mutation)**

The Thermodynamic Revolution



The Thermodynamic Revolution

- **Being vs Becoming**
 - **Classical Physics: the world as a static and reversible system that undergoes no evolution, whose information is constant in time**
 - **Classical physics is the science of being**
 - **Thermodynamics describes an evolving world in which irreversible processes occurs**
 - **Thermodynamics is the science of becoming**
 - **The science of being and the science of becoming describe dual aspects of nature**

The Thermodynamic Revolution

- **Entropy**
 - Clausius' entropy (1850): any transformation of energy has an energetic cost
 - Heat flows spontaneously from hot to cold bodies, but the opposite never occurs
 - Scrambled eggs and lumps of sugar
 - Natural processes generate entropy
 - Second law of thermodynamics : entropy (of an isolated system) can never decrease
 - We cannot always replay the history of the universe backwards
 - Some processes are **irreversible**
 - **Time's arrow**

The Thermodynamic Revolution

- **Ludwig Boltzmann (1877)**
 - **Statistical Mechanics**
 - **Many different microscopic states of a system result in the same macroscopic state**
 - **Boltzmann's statistical definition of entropy: the entropy of a macrostate is the logarithm of the number of its microstates**
 - **$E = K * \text{Log}(N)$**
 - **Macrostates that can be implemented only by one microstate are perfectly ordered states**
 - **Entropy is a measure of **disorder** in a system**

The Mathematical Revolution

The Mathematical Revolution

- **George Boole (1854)**
 - **Systematic use of symbols eliminates the ambiguities of natural language**
 - **Logic becomes as rigorous as Mathematics**
 - **“All humans are mortal” translates into “All y are some x” or $y=vx$, and can be further derived: $y-vx=0$, “Non-mortal humans do not exist”**

The Mathematical Revolution

- **Charles Babbage: "Difference Engine" (1859),
manufactured by Edvard Scheutz**



The Mathematical Revolution

- **Georg Cantor (1879)**
 - **Set Theory: emancipates Mathematics from its traditional domain (numbers)**
 - **Transfinite numbers**
- **Gottlob Frege (1884)**
 - **“Predicate calculus”**
 - **Mathematics becomes a branch of Logic**
 - **The laws of thought “are” the laws of logic**
- **Russell & Whitehead (1913): Axiomatization of Mathematics**
- **Wittgenstein (1921): Axiomatization of Language**

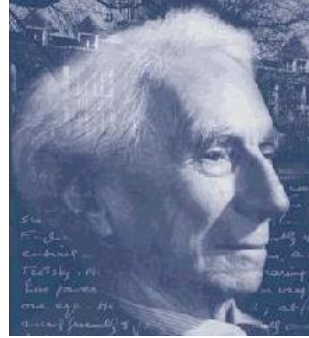
The Mathematical Revolution

- **David Hilbert (1900)**
 - **Entscheidungsproblem: does a general algorithmic procedure for resolving all mathematical problems exist?**



The Mathematical Revolution

- **Logic**
 - **Paradoxes**
 - **"I am lying"**
 - **The class of classes that do not belong to themselves ("the barber who shaves all barbers who do not shave themselves")**
 - **The omnipotent god**
 - **Kurt Goedel's theorem of incompleteness (1931)**



Goedel

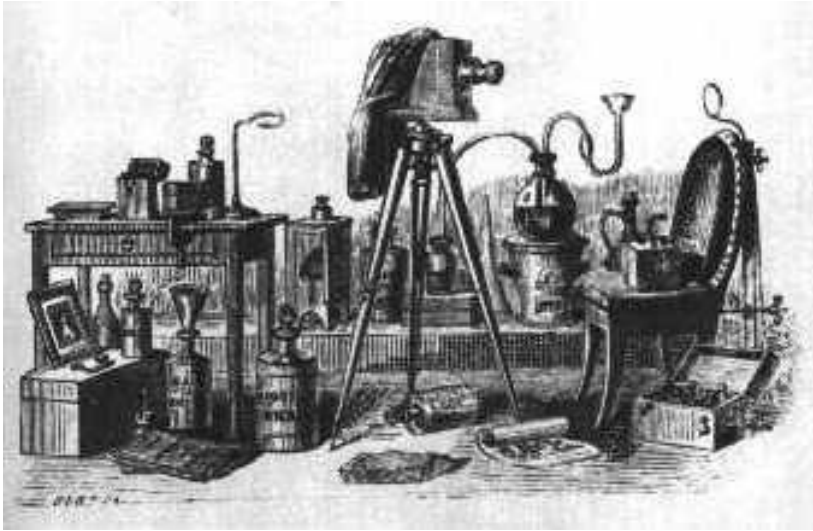


The Mathematical Revolution

- **What is an algorithm**
 - **Alan Turing: definition of algorithm via the Turing machine (1936)**
 - **Alonzo Church (1936): definition of algorithm via Lambda calculus**
 - **Turing's and Church's conclusion: Hilbert's Entscheidungsproblem is impossible (there is no universal algorithm for deciding whether or not a Turing machine will stop)**
 - **Universal Turing Machine**



The Electrical Revolution



The Electrical Revolution

- **1890: AEG develops the AC motor and generator (first power plants) and alternating current makes it easy to transmit electricity over long distances**
- **Impact**
 - **Domestic life (appliances)**
 - **Entertainment (media)**
 - **Office life (office equipment)**

The Electrical Revolution

Media

1876: Alexander Bell's telephone

1877: Thomas Edison's phonograph

1886: Kodak's first consumer camera

1892: popular music becomes big business

1895: the Lumiere brothers invent cinema

1901: Guglielmo Marconi conducts the first transatlantic radio transmission



The Electrical Revolution

Media

1926: films with synchronized voice and music are introduced (talking movies)

1927: the juke-box is introduced by Automatic Music Instrument

1927: Philo Farnsworth invents the television in San Francisco

1940: Peter Goldmark invents color television

Tv Set Model 817 (1938)
(Museum of Science, London)



The Electrical Revolution

Appliances

1886: Josephine Cochrane invents the dishwasher

1902: Willis Carrier invents the air conditioner

**1911: General Electric introduces the first
commercial refrigerator**

1946: Percy Spencer invents the microwave oven

The Electrical Revolution

Office

**1868: Christopher Latham Sholes
invents the first practical typewriter**

**1884: James Ritty invents the cash
register**

**1885: William Burroughs develops an
adding machine**

**1890: Herman Hollerith builds an
electrical tabulating device (Hollerith
renamed IBM in 1924)**

**1937: Chester Carlson invents the
photocopier**



Burroughs' calculator (1897)
(Museum of Science, London)

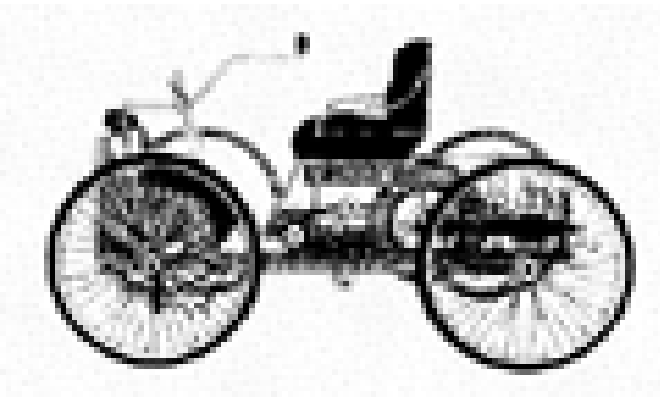
The Transport Revolution



Benz's car of 1886 (a carriage without horses)



The USA's first commercial automobile (Duryea, 1893)



Henry Ford's first automobile (1896)

The Transport Revolution

Automobile

1885: Daimler and Maybach invent the motorcycle

1886: Karl Benz builds a gasoline-powered car

1913: Ford installs the first assembly line

The Transport Revolution

- The automobile in the 1920s



The Transport Revolution

- The automobile in the 1930s



The Transport Revolution

- The automobile in the 1940s



The Transport Revolution

- The North Atlantic transatlantic liners
 - 1929-38: Golden age
 - Germany's "Bremen" and "Europa", Italy's "Rex", France's "Normandie" (1934), Britain's "Queen Mary" (1936)
 - Britain-New York: 4 days



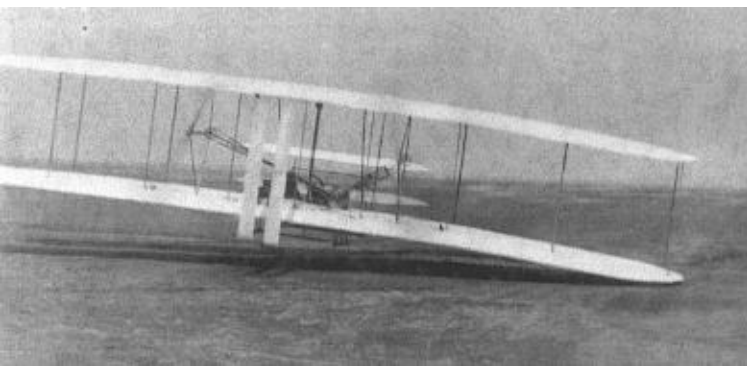
Queen Mary



The Transport Revolution

- The Airplane
 - 1873: baron Friedrich von Harbou of Prussia invents the dirigible
 - **1903: Wilbur and Orville Wright fly the first airplane**
 - 1909: Louis Bleriot crosses English Channel in a monoplane
 - 1915: German zeppelins bomb Britain (first air raid)
 - 1915-18: France builds 67,987 planes, Britain 58,144 and Germany 48,537, Italy 20,000 and the USA 15,000

Wright brothers, 1903



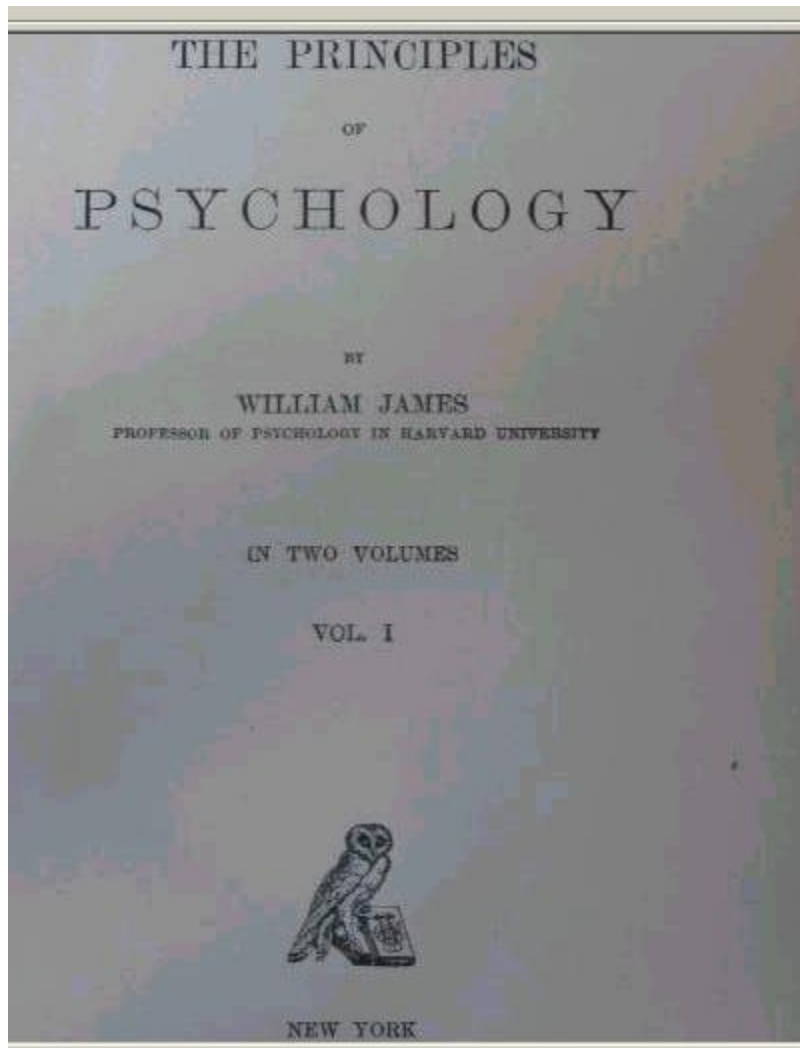
Germany's Fokker combat aircraft (1918)



The Transport Revolution

- **The Airplane**
 - **1918: United States Post Office establishes airmail service**
 - **1919: Walter Hinton pilots a plane from the USA to Lisbon, the first transatlantic flight (with many stops)**
 - **1919: British pilots fly from Newfoundland to Ireland, the first nonstop transatlantic flight (in 16 hours)**
 - **1920: Aircraft Travel and Transport inaugurates London–Paris passenger service**
 - **1923: John Macready and Oakley Kelly fly a plane nonstop from New York to San Diego, the first transcontinental flight**
 - **1924: USA planes fly around the world (in 175 days)**
 - **1927: Charles Lindbergh flies New York to Paris**

The Psychological Revolution



The Psychological Revolution

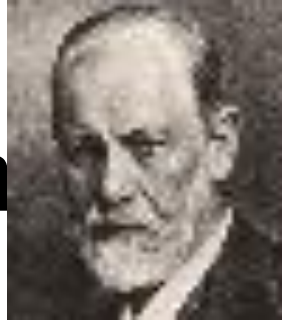
- **Wilhelm-Max Wundt (1874)**
 - **Actions have a motive**
 - **Motives are mental states, hosted in our minds and controlled by our minds**
 - **Motives express an imbalance in the mind, between desire and reality**
 - **Action is an attempt to regenerate balance by changing the reality to match our desire**



The Psychological Revolution

- **William James (1890)**
 - **The function of mind is to help the body live in an environment**
 - **The brain is an organ that evolved because of its usefulness for survival**
 - **Consciousness is not a substance, it is a process (“the stream of consciousness”)**

The Psychological Revolution



- **Sigmund Freud (1900)**
 - **Classical view of dreams: dreams are about the future (oracles)**
 - **Freud's view of dreams: dreams are about the past**
 - **The mind is divided in conscious (rational motives) and unconscious mind (reservoir of unconscious motives)**
 - **Separation of motive and awareness**

The Psychological Revolution



- **Edward Thorndike (1911)**
 - **Animals learn based on the outcome of their actions ("law of effect")**
 - **The mind is a network**
 - **Learning occurs when elements are connected**
 - **Behavior is due to the association of stimuli with responses that is generated through those connections**
 - **A habit is a chain of “stimulus-response” pairs**

The Psychological Revolution

- **Behaviorism deals with mental terms only to the extent that they are related to behavior**
 - **John Watson (1913):**
 - **Stimulus-response patterns explain animal behavior**
 - **Ivan Pavlov (1926)**
 - **Conditioned reflexes**
 - **Burrhus Skinner (1938)**
 - **Therapy is not about releasing repressed impulses but about conditioning brains in order to correct disordered behavior**

The Psychological Revolution

- **Gestalt Psychology**
 - **An individual stimulus does not cause an individual response**
 - **Form is the elementary unit of perception: we do not construct a perception by analyzing a myriad data, we perceive the form as a whole**
 - **Max Wertheimer (1912)**
 - **Perception is more than the sum of the things perceived**
 - **Form is the elementary unit of perception**
 - **Wolfgang Kohler (1925)**
 - **Problem-solving as sudden insight**
 - **Restructuring of the field of perception**

The Psychological Revolution

- **Gestalt Psychology**
 - **Karl Lashley (1930)**
 - **Functions are not localized but distributed around the brain**
 - **Every brain region partakes (to some extent) in all brain processes**
 - **The brain as a whole is “fault tolerant”**
 - **Memory as an electromagnetic field and a specific memory as a wave within that field**

The Psychological Revolution



- **Jean Piaget (1923)**
 - The mind grows, just like the body grows
 - Progress from simple mental arrangements to complex ones (from literal to abstract)
 - Not by gradual evolution but by sudden rearrangements of mental operations
 - Cognitive growth = transition from a stage in which the dominant factor is perception, which is irreversible, to a stage in which the dominant is abstract thought, which is reversible

The Psychological Revolution

- **Cognitive Psychology**
 - **Richard Semon (1904): the “engram”**
 - **Otto Selz (1920s): schema**
 - **Fredrick Bartlett (1932): Reconstructive memory**
 - **Edward Tolman (1932): “cognitive map”**
 - **Donald Broadbent (1957): "short-term memory" and "long-term memory"**

Physics

- **Cosmological Revolution**
- **Subatomic Revolution**
- **A new understanding of physical reality**
- **Largely due to the properties of light**

The Cosmological Revolution

“As an older friend I must advise you against it for in the first place you will not succeed, and even if you succeed no one will believe you”

(Planck to Einstein in 1913)

[illegible]

The Cosmological Revolution

- **Georg Riemann (1854)**
 - **General class of geometries, that comprises the classical Euclidean geometry as a special case**
 - **Spaces with any number of dimensions**
 - **Space can be curved instead of flat**

The Cosmological Revolution



- **Ernst Mach (1886)**
 - **Newton's inertia: a fundamental property of matter**
 - **Mach's inertia: a local property that arises from the global distribution of matter in the universe**
 - **All motion is “relative” motion (relative to all other masses)**

The Cosmological Revolution



- **Henri Poincaré` (1892)**
 - The speed of light is the maximum speed
 - Non-Euclidean geometries have the same logical and mathematical legitimacy as Euclidean geometry

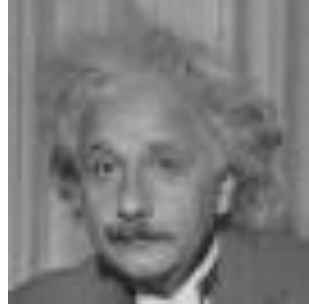
The Cosmological Revolution



- **Hendrik Lorentz (1892)**
 - **Unify Newton's equations for the dynamics of bodies and Maxwell's equations for the dynamics of electromagnetic waves in one set of equations (Lorentz transformations)**
 - **Contraction of bodies**

The Cosmological Revolution

- **Albert Einstein (1905)**
 - **Special relativity:**
 - **Laws of nature must be the same in all frames of reference that are "inertial"**
 - **The speed of light is the same in all directions**



The Cosmological Revolution

- **Special Relativity**
 - **Consequences:**
 - **The length of an object and the duration of an event are relative to the observer**
 - **All quantities must have four dimensions, a time component and a space component (e.g., energy-momentum)**
 - **Equivalence of mass and energy ($E=mc^2$)**
 - **Nothing can travel faster than light**
 - **Time does not flow (no more than space does), it is just a dimension**

The Cosmological Revolution

- **General Relativity (1917)**
 - Relativity for systems accelerated with respect to one another
 - Principle of Equivalence: Forces produced by gravity are in every way equivalent to forces produced by acceleration
 - All forces (gravitational or not) are due to acceleration
 - Newton's hypothesis that every object attracts every other object is unnecessary

The Cosmological Revolution

- **General Relativity**
 - **Masses curve spacetime**
 - **Spacetime's curvature determines the motion of masses.**
 - **Einstein's law of gravity: Every object, which is not subject to external forces, moves along a geodesic of spacetime (the shortest route between two points on a warped surface), its “world line”**
 - **Spacetime “is” the gravitational field**
 - **It is spacetime that is curved, not the trajectory**

The Cosmological Revolution

- **General Relativity**
 - Time too is warped
 - Clocks slow down in a gravitational field
 - Light too travels in a warped spacetime
 - Light is deflected by a gravitational field

The Cosmological Revolution

- **Albert Einstein**
 - **Cosmological constant to counterbalance the effect of gravity, so as to retain a static universe**

The Cosmological Revolution

Physics

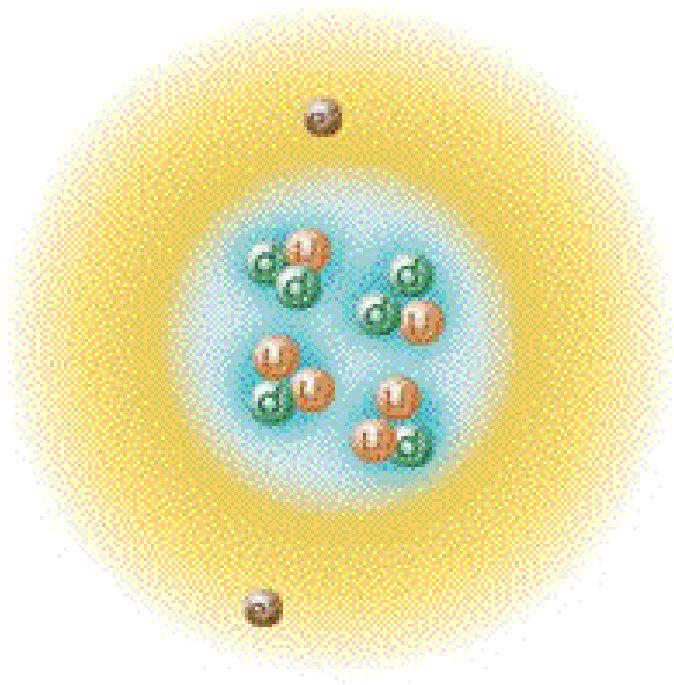
1920: Arthur Eddington suggests that nuclear fusion fuels the sun

1929: Edwin Hubble discovers that the universe is expanding

1936: Fritz Zwicky compiles a catalogue of 10,000 clusters each made of thousands of galaxies

Astronomical observations reveal a turbulent universe made of millions of galaxies and punctuated by violent events

The Subatomic Revolution



The Subatomic Revolution

Waves

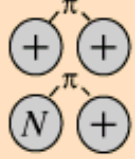
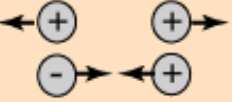
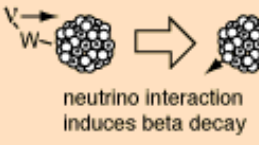
- **1887: Heinrich Herz discovers radio waves**
- **1895: Wilhelm Conrad Roentgen discovers X rays**
- **1896: Antoine Henri Becquerel, Pierre Curie and Marie Curie observe the radioactive decay of atomic nuclei**

The Subatomic Revolution

- **Electrons**
 - **Hendrik Lorentz (1892):** the atom is not elementary but is made smaller units that are electrical in nature
 - **Ernest Rutherford (1911):** the atom is made of a nucleus and orbiting electrons (a mini-solar system)
 - **Niels Bohr (1913):** Electrons are arranged in concentric shells outside the nucleus of the atom
 - **Robert Millikan (1913):** the charge of the electron
 - **James Chadwick (1932):** The nucleus of the atom contains charge-less particles (neutrons)
 - **Enrico Fermi (1933):** a “weak force” holds together some subatomic particles

The Subatomic Revolution

- Elementary forces:
 - Electromagnetic force
 - Gravitational force
 - Nuclear force
 - Weak force

Fundamental Forces				
<i>Strong</i>		Strength 1	Range (m) 10^{-15} (diameter of a medium sized nucleus)	Particle gluons, π (nucleons)
<i>Electro-magnetic</i>		Strength $\frac{1}{137}$	Range (m) Infinite	Particle photon mass = 0 spin = 1
<i>Weak</i>		Strength 10^{-6}	Range (m) 10^{-18} (0.1% of the diameter of a proton)	Particle Intermediate vector bosons W^+ , W^- , Z_0 , mass > 80 GeV spin = 1
<i>Gravity</i>		Strength 6×10^{-39}	Range (m) Infinite	Particle graviton ? mass = 0 spin = 2

The Subatomic Revolution

- **Quantum Mechanics**
 - **First major theory of a dimension that humans cannot perceive (the infinitely small)**
 - **Humans were not built by evolution to understand the quantum world**
 - **Quantum Mechanics reaches conclusions that are at odds with the world that humans were designed to cope with (indeterminacy, the observer collapses the wave, the vacuum is not empty, antimatter, etc)**
 - **Only “interpretations” of what it means are possible: we cannot verify its meaning because its meaning lies beyond our cognitive closure**

The Subatomic Revolution

- **Quantum Mechanics**
 - **A consequence of the electric revolution: the study of electricity led to the study of the atom**
 - **A German phenomenon: Germany was at the vanguard of the electric revolution**

The Subatomic Revolution

- **Quantum Mechanics**
 - **Energy quanta (1900):** atoms can emit energy only in discrete amounts (Max Planck)
 - **Energy-frequency equivalence (1905):** the energy of a photon is proportional to the frequency of the radiation, i.e. light is particles (Albert Einstein)
 - **Structure of the atom (1913):** electrons turn around the nucleus and are permitted to occupy only some orbits (Niels Bohr)
 - **Dualism (1923):** waves and particles are dual aspects (Louis de Broglie)
 - **Wave function (1926):** wave of probabilities (Max Born)
 - **Anti-matter (1928):** positively charged electron (Paul Dirac): Quantum Electrodynamics



The Subatomic Revolution



- **Quantum Mechanics**
 - The state of a particle is described by a “wave function” which summarizes (“superposes”) all the alternatives and their probabilities
 - Erwin Schrodinger's equation describes how this wave function evolves in time
 - The wave function describes a set of possibilities
 - A measurement causes a “collapse of the wave function”: only one eigenvalue is possible after the measurement, the one that is measured
 - A measurement introduces irreversibility: the collapse cannot be undone

The Subatomic Revolution

- **Quantum Mechanics**
 - **Werner Heisenberg's "uncertainty principle": there is a limit to the precision with which we can measure quantities**



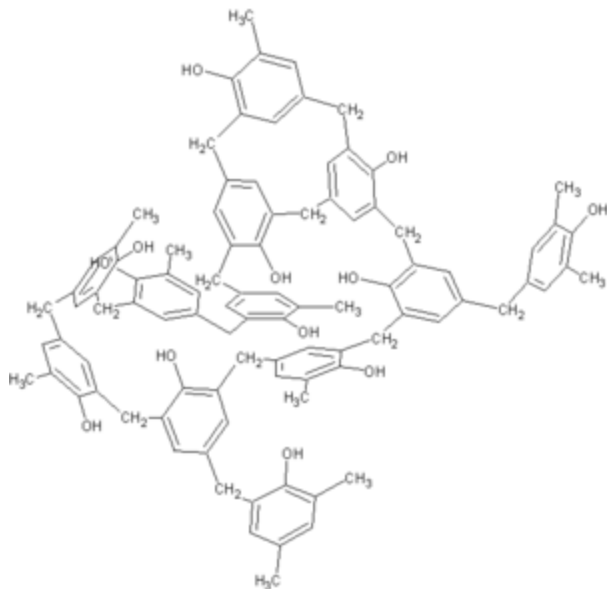
The Subatomic Revolution

- **Quantum Mechanics**
 - **Forces are due to exchanges of discrete amounts of energy (“quanta”)**
 - **Equivalent descriptions: wave and particle, energy and mass, frequency and wavelength**
 - **Space-time is discrete**
 - **The vacuum is not empty (“zero point” radiation)**
 - **There is a limit to how small a physical system can be**
 - **Randomness**
 - **Non-locality**

The Subatomic Revolution

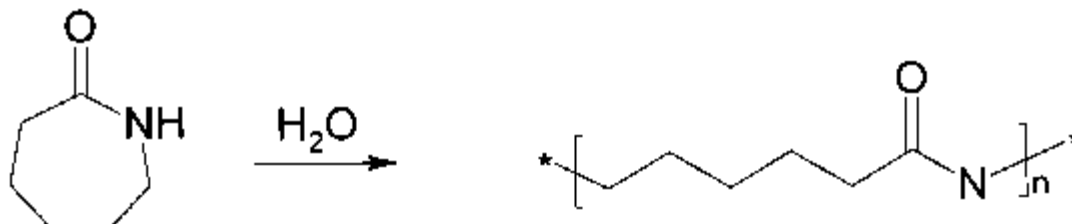
- **Interpretations of Quantum Mechanics**
 - **Niels Bohr: only phenomena are real**
 - **Werner Heisenberg: the world "is" made of possibility waves (particles are merely "potentialities")**
 - **Albert Einstein: an incomplete description of the universe ("hidden variables")**
 - **John Von Neumann: consciousness**
 - **Paul Dirac: our knowledge of a system**
 - **David Bohm: a quantum potential acts beyond the 4-dimensional geometry of spacetime**
 - **Hugh Everett: a multiverse**

The Synthetic Revolution



Bakelite

Nylon 6



The Synthetic Revolution

Synthetic materials

1907: Leo Baekeland invents the first plastic ("bakelite")

1925: Cellophane is introduced

1930: Polystyrene is invented

1933: Eric Fawcett and Reginald Gibson invent polyethylene

1935: Wallace Carothers invents nylon, a synthetic substitute for silk

1938: Roy Plunkett invents teflon

1942: DuPont invents polyethylene plastic

1945: Ed Tupper founds Tupperware for food containers made of polyethylene

Third Scientific Revolution

- **World War II**
- **Cold War**

**The Electrical Revolution
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The Mathematical Revolution**



**The Electronic Revolution
The Tourism revolution
The Space Revolution
The Digital Revolution
The Cognitive Revolution
The Theoretical Revolution
The Genetic Revolution**

Third Scientific Revolution

- **World War II inventions**
 - **Computer (Tommy Flowers, Britain, 1943, vs Konrad Zuse, Germany, 1914)**
 - **Nuclear power (Enrico Fermi, USA, 1942, vs Werner Heisenberg, Germany, and Yoshio Nishina, Japan)**
 - **Rocket (Wernher von Braun, Germany, 1942)**

Third Scientific Revolution

- **Cold War inventions**
 - **Spaceships**
 - **Internet**
 - **GPS**

The Electronic Revolution

- **Electronics**
 - **1947: William Shockley invents the transistor**
 - **1954: first transistor radio**

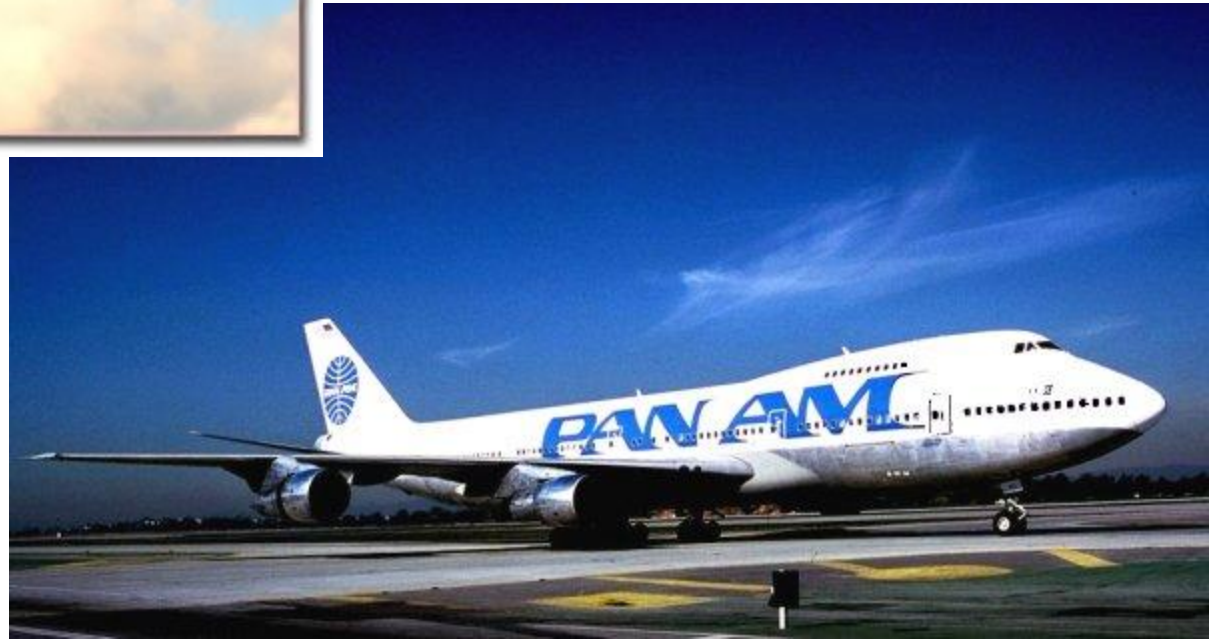
The Electronic Revolution

- **Office (1950s)**
 - **Electric Typewriter**
 - **Calculating Machine**
 - **Photocopier**
 - **Telefax**
 - **Telex (1958)**
 - **Touch-tone Phone (1963)**
 - **Hand-held Calculator (1967)**
 - **IBM Computers (1964)**

The Electronic Revolution

- **Media**
 - **1948: 12-inch 33-1/3 RPM long-playing vinyl record**
 - **1962: the audio cassette**
 - **1971: the video-cassette recorder (VCR)**
 - **1973: Martin Cooper at Motorola invents the cellular telephone**
 - **1978: the USA begins installation of the GPS**
 - **1979: Sony launches the "Walkman" portable stereo**
 - **1981: the compact disc (CD)**
 - **1989: Magellan Corporation introduces the first hand-held GPS receiver**
 - **1995: the DVD**

The Tourism Revolution



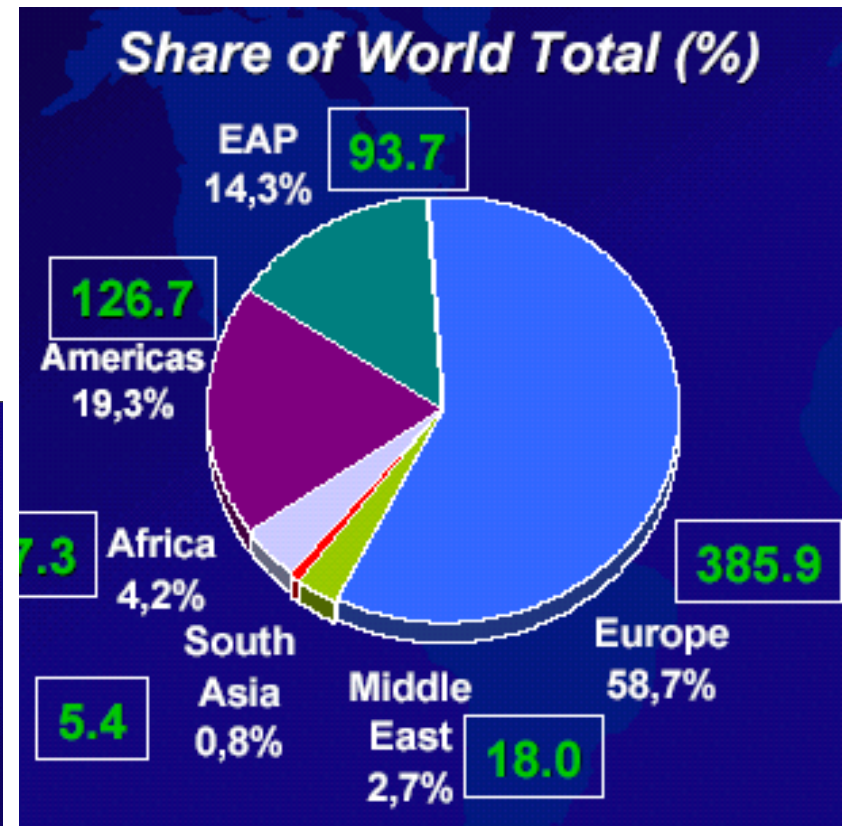
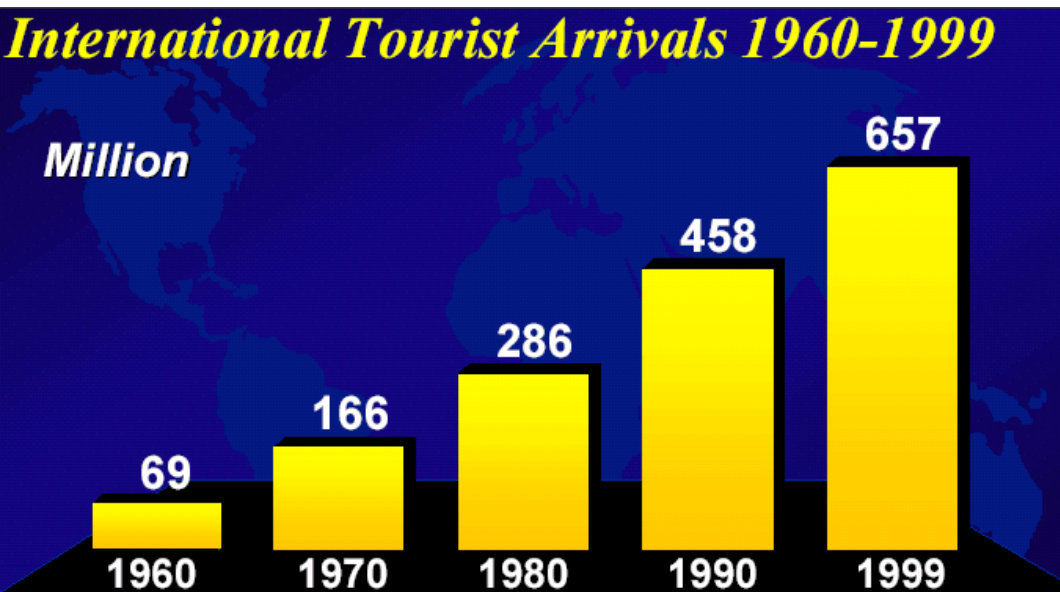
The Tourism Revolution

– Transportation

- **Pan Am's first transatlantic flight (1939)**
- **Boeing 707: long-distance jet (1958)**
 - **East Coast to West Coast in five hours instead of three days**
 - **New York to London in eight hours instead of five days**
 - **Decline of passenger ships and railroads**
- **Shinkansen (1964)**
- **Wide-body jet (1967)**

The Tourism Revolution

- Transportation
 - Cheap transportation enables the age of mass tourism



(WTO 1999)

The Space Revolution

Neil Armstrong on the Moon (July 1969)



The Space Revolution

Space exploration

1957: the Soviet Union launches the first artificial satellite (Sputnik)

1961: Yuri Gagarin becomes the first astronaut

1962: the USA launches the first telecommunication satellite (Telstar)

1969: Neil Armstrong is the first human to walk on the Moon



Vostok spaceship



Telstar



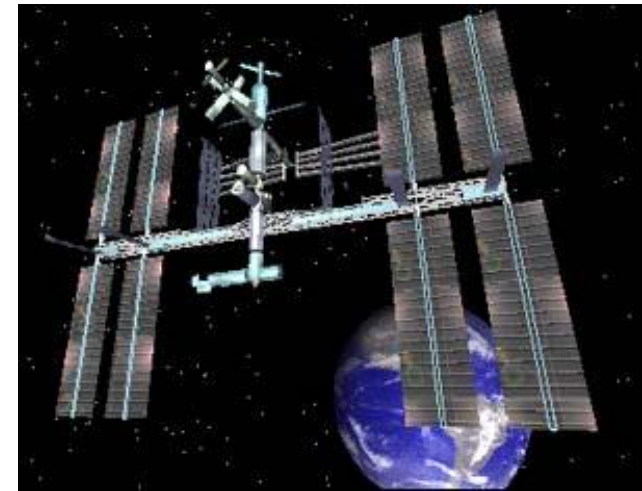
The Space Revolution

- **Space exploration**
 - **1970: First spacecraft on Venus (Soviet)**
 - **1971: First spacecraft on Mars (Soviet)**
 - **1977: the USA launches the Voyager to reach other galaxies**
 - **1981: the USA launches the first space shuttle**
 - **1986: the USSR launches the permanent space station MIR**
 - **1990: the Hubble space telescope is launched**

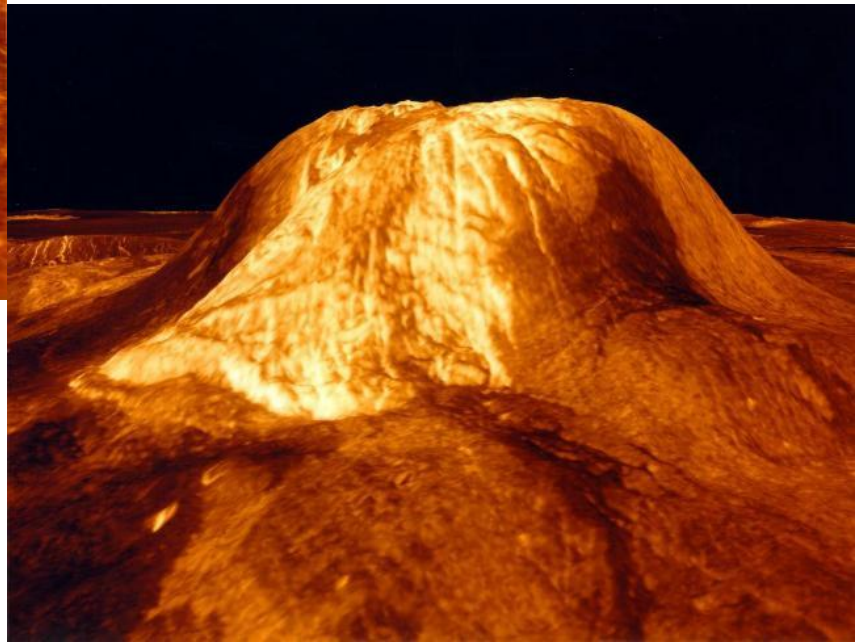
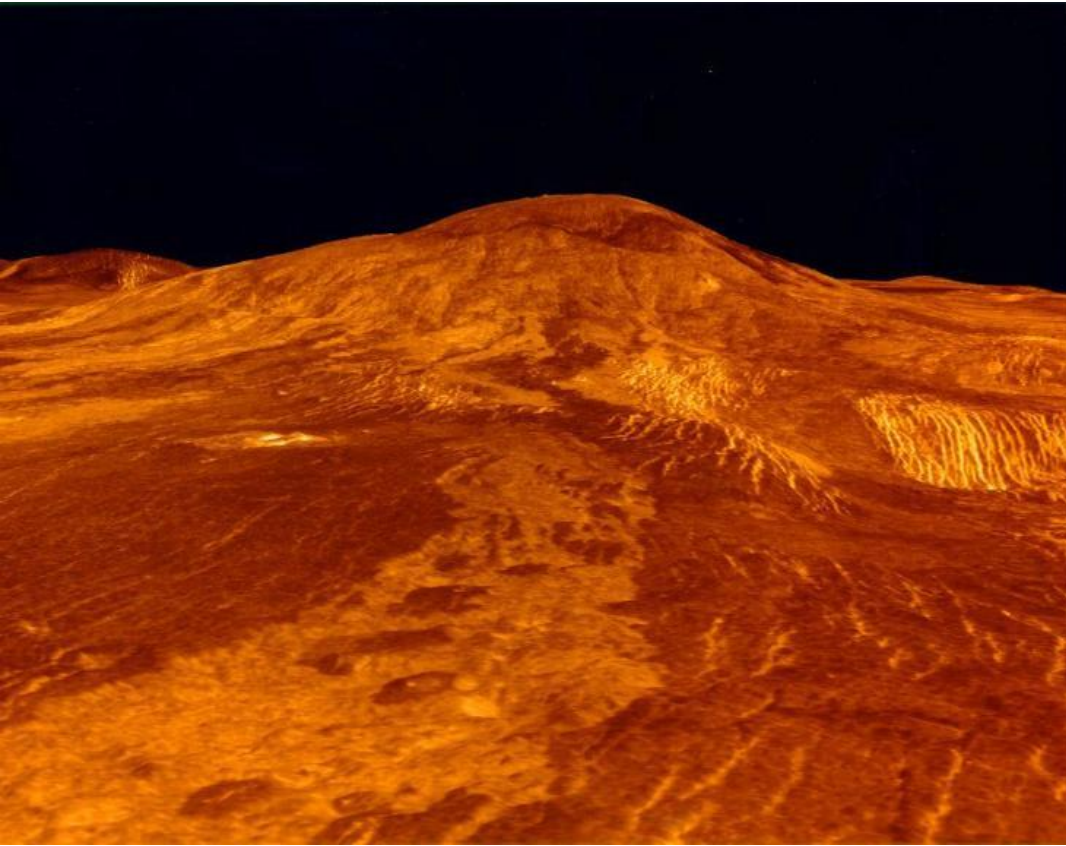


The Space Revolution

- **Space Exploration**
 - **1994: Astronomers discover an invisible object of 2.5 billion to 3.5 billion solar masses at the center of the galaxy M87 (first evidence of a black hole)**
 - **2000: First mission to the International Space Station**
 - **2001: the Voyager leaves the solar system**
 - **2003: several unmanned space-crafts land on Mars**



The Space Revolution





Mars, January 2004



Husband Hill, Mars, September 2005





The first galaxies
that developed
after the Big
Bang
(Hubble
Telescope, 2004)

The Space Revolution



First photograph of a non-solar planet
(NASA 2005)



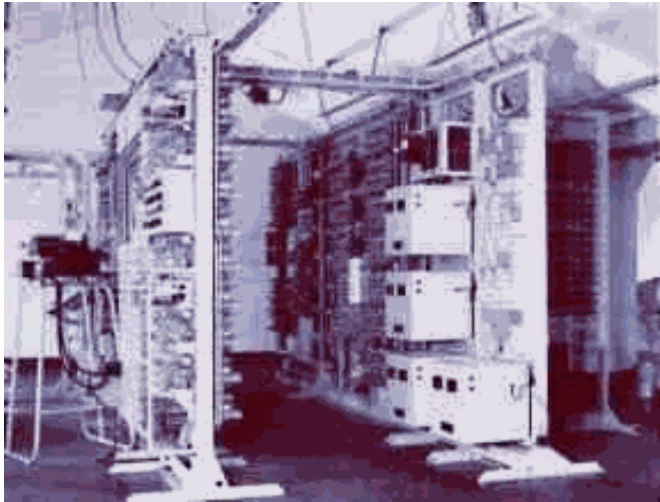
Location of the Cygnus X-1 black hole
(NASA 2004)

The Space Revolution

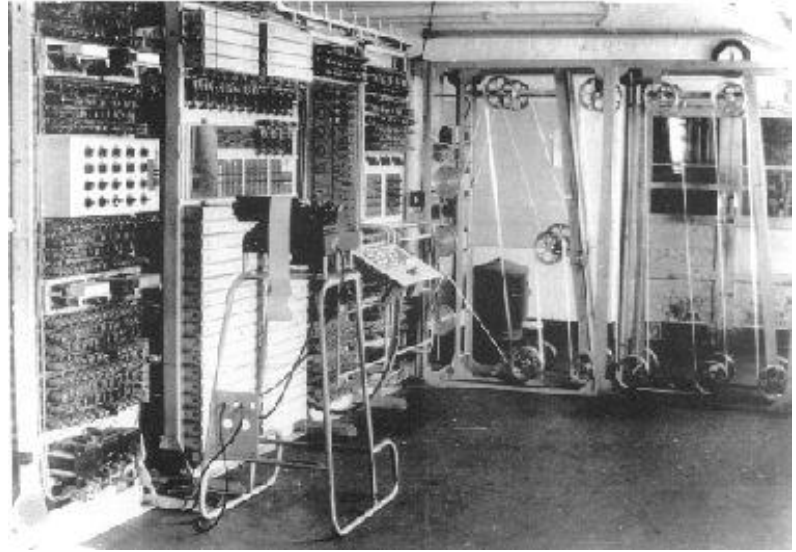
Astronomy

- 50 billion galaxies in the universe
- 200 billion stars in the Milky Way (our galaxy)
- Nine planets around the Sun (our star)
- One light-year = 9,461 billion km
- Pluto (last solar planet) = 5.9 billion kms from the Sun (less than 0.001 light-years)
- Alpha Centauri (nearest star) = 4.3 light-years
- Sirius (brightest star in the sky) = 8.7 light-years
- Center of the Milky Way = 26,000 light-years from the Sun
- Andromeda (nearest galaxy) = 2.2 million light-years

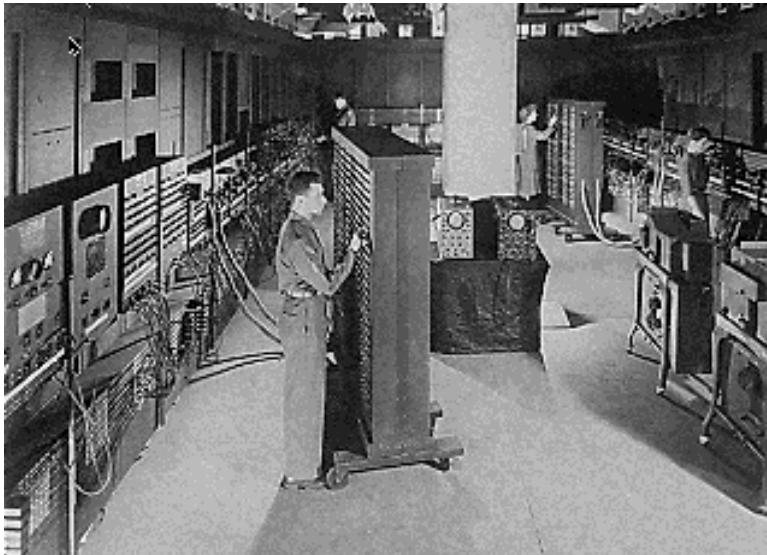
The Digital Revolution



Colossus



Univac 1951



Eniac 1947



IBM /360

The Digital Revolution

Computer

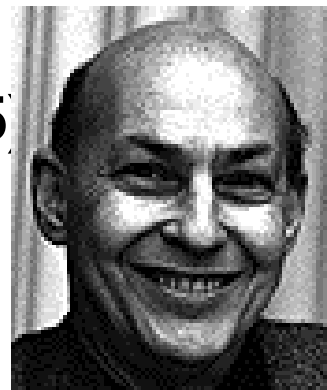
- **1943: the Colossus (Alan Turing and others)**
- **1946: the first non-military computer, ENIAC, is unveiled**
- **1947: William Shockley invents the transistor at Bell Labs**
- **1951: The first commercial computer is built, the Univac**
- **1955: Artificial Intelligence**
- **1956: Robert Noyce and Jack Kilby invent the microchip**
- **1958: Texas Instruments builds the first integrated circuit**
- **1964: IBM introduces the 360 series**
- **1965: Gordon Moore predicts that the processing power of computers will double every 18 months**
- **1965: DEC introduces the first mini-computer, the PDP-8, that uses integrated circuits**

The Digital Revolution

Software

- **1958: Jim Backus (at IBM) invents the FORTRAN programming language, the first machine-independent language**
- **1962: Paul Baran proposes a distributed network as the form of communication least vulnerable to a nuclear strike**
- **1964: IBM introduces the first "operating system" for computers (the OS/360)**
- **1968: The Arpanet is established based on Baran's idea (four nodes: UCLA, Stanford Research Institute, UCSB, University of Utah)**
- **1969: the Unix operating system**
- **1972: Ray Tomlinson invents e-mail**

The Digital Revolution



- **Machine Intelligence**
 - **Alan Turing's test (1947)**
 - **John Von Neumann's self-reproducing automaton (1947)**
 - **Norman Wiener's Cybernetics (1947)**
 - **Claude Shannon's Theory of Information (1948)**
 - **John McCarthy's Artificial intelligence (1955)**
 - **Neural Networks (1957)**
 - **Herbert Simon & Allen Newell: physical symbol processor**
 - **Expert Systems/ Knowledge Engineering (1965)**
 - **Common Sense**
 - **John Holland's Genetic Algorithms (1975)**

The Digital Revolution

- **Computers**

1971: Intel invents the micro-processor

1974: the first personal computer, Altair 8800

1977: Atari introduces the first video game console

1977: Steve Jobs and Steve Wozniak develop the Apple II

1981: IBM introduces the PC ("Personal Computer")



The Digital Revolution

- **Software**
 - **1979: Dan Bricklin develops Visicalc, a spreadsheet application for the Apple II**
 - **1981: the IBM PC runs DOS, an operating system developed by Bill Gates' Microsoft**
 - **1983: Jonathan Sachs develops Lotus 1-2-3, a spreadsheet application for DOS**
 - **...**
 - **1999: the world prepares for the new millennium amidst fears of computers glitches due to the change of date (Y2K)**
 - **1999: Microsoft is worth 450 billion dollars, the most valued company in the world**

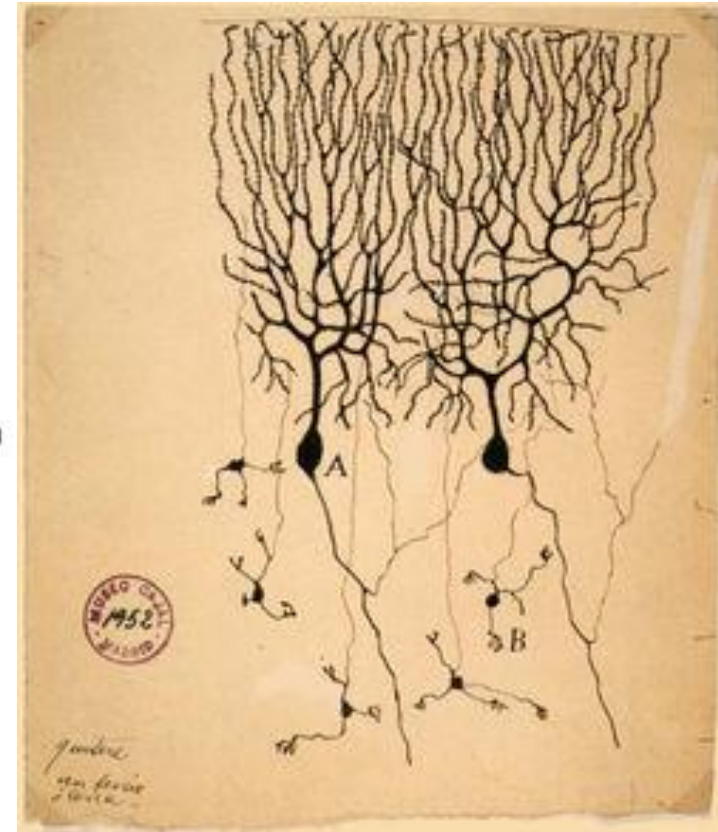
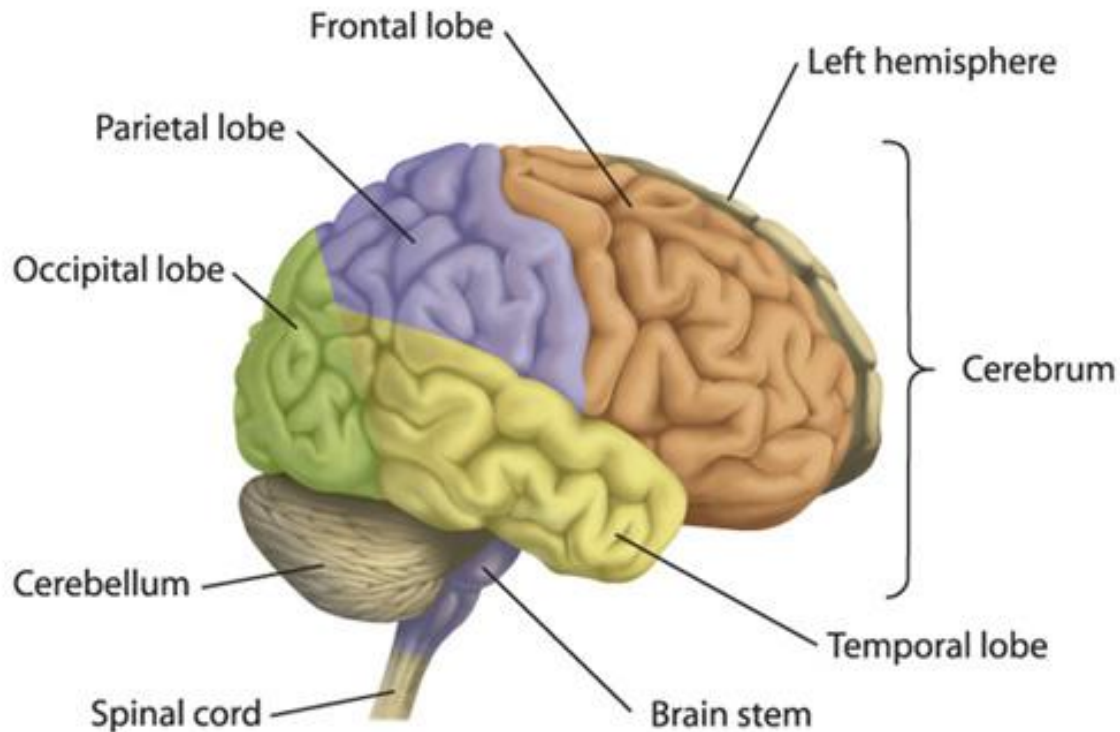
The Digital Revolution

- **Internet**
 - **1991: the World-Wide Web (invented by Tim Berners-Lee) debuts on the Internet**
 - **1993: Marc Andreessen develops the first browser for the World Wide Web (Mosaic)**
 - **1994: Jerry Yang launches the first search engine, Yahoo**
 - **1994: Four million people use the Internet**
 - **1999: Weblogs (Blogs)**

The Digital Revolution

- **Net Society**
 - **E-commerce: decline of the brick-and-mortar store**
 - **E-mail: first innovation in written personal communication since the invention of mail**
 - **World-wide web: largest knowledge base in history**
 - **News websites: first major innovation in newscasting since tv news**

The Cognitive Revolution



Neuron
(Drawing by Santiago
Ramón y Cajal)

The Cognitive Revolution

- **The Brain**
 - **1949: Donald Hebb's selective strengthening of synapses and cell assemblies**
 - **1950s: Electrical activity of the brain**
 - **1960s: Neurons communicate via chemicals ("neurotransmitters")**
 - **1960s: The left hemisphere is dominant for language and speech, the right hemisphere excels at visual and motor tasks**

The Cognitive Revolution



- **Noam Chomsky (1957)**
 - Human brains are designed to acquire a language
 - They contain a "universal grammar"
 - We speak because our brain is meant to speak
 - Behaviorists: we are trained to learn the meaning of sentences.
 - Chomsky: we understand sentences that we have never encountered before.

The Cognitive Revolution

- **Michel Jouvet (1962)**
 - REM (Rapid eye movement)
 - During REM sleep several areas of the brain are working frantically, and some of them are doing exactly the same job they do when the brain is awake.

The Cognitive Revolution

- **Evolutionary Psychology**
 - **Darwinian thinking applied to the social behavior of animals**
 - **William Hamilton: "The Genetic Evolution of Social Behavior" (1963)**
 - **George Williams (1966)**
 - **Robert Trivers: "The Evolution of Reciprocal Altruism" (1971)**
 - **John Maynard-Smith**

The Cognitive Revolution

- **Evolutionary Psychology**
 - **Evolutionary Psychology studies human nature**
 - **Most behavior is mechanical, instinctive, although it makes a lot of sense: all the "thinking" has already been done by natural selection and summarized in DNA**
 - **Genes determine behavior that has been found to be rational over thousands of years**
 - **A new kind of "unconscious"**

The Cognitive Revolution

- **Niels Jerne (1968)**
 - **Immune system as a Darwinian system**
 - **The immune system routinely manufactures all the antibodies it will ever need**
 - **When the body is attacked by foreign antigens some antibodies are selected**

The Cognitive Revolution

- **Neural Darwinism**
 - The mind already knows the solution to all the problems that can occur in the environment in which it evolved over millions of years
 - The mind knows what to do, but it is the environment that selects what it actually does

The Cognitive Revolution

- **Consciousness**
 - **Space-based binding**
 - **Time-based binding**

The Cognitive Revolution

- **Unsolved mysteries**
 - **The nature and source of consciousness**

The Theoretical Revolution

***"The most incomprehensible thing
about the universe is that it is
comprehensible"***

Albert Einstein

The Theoretical Revolution

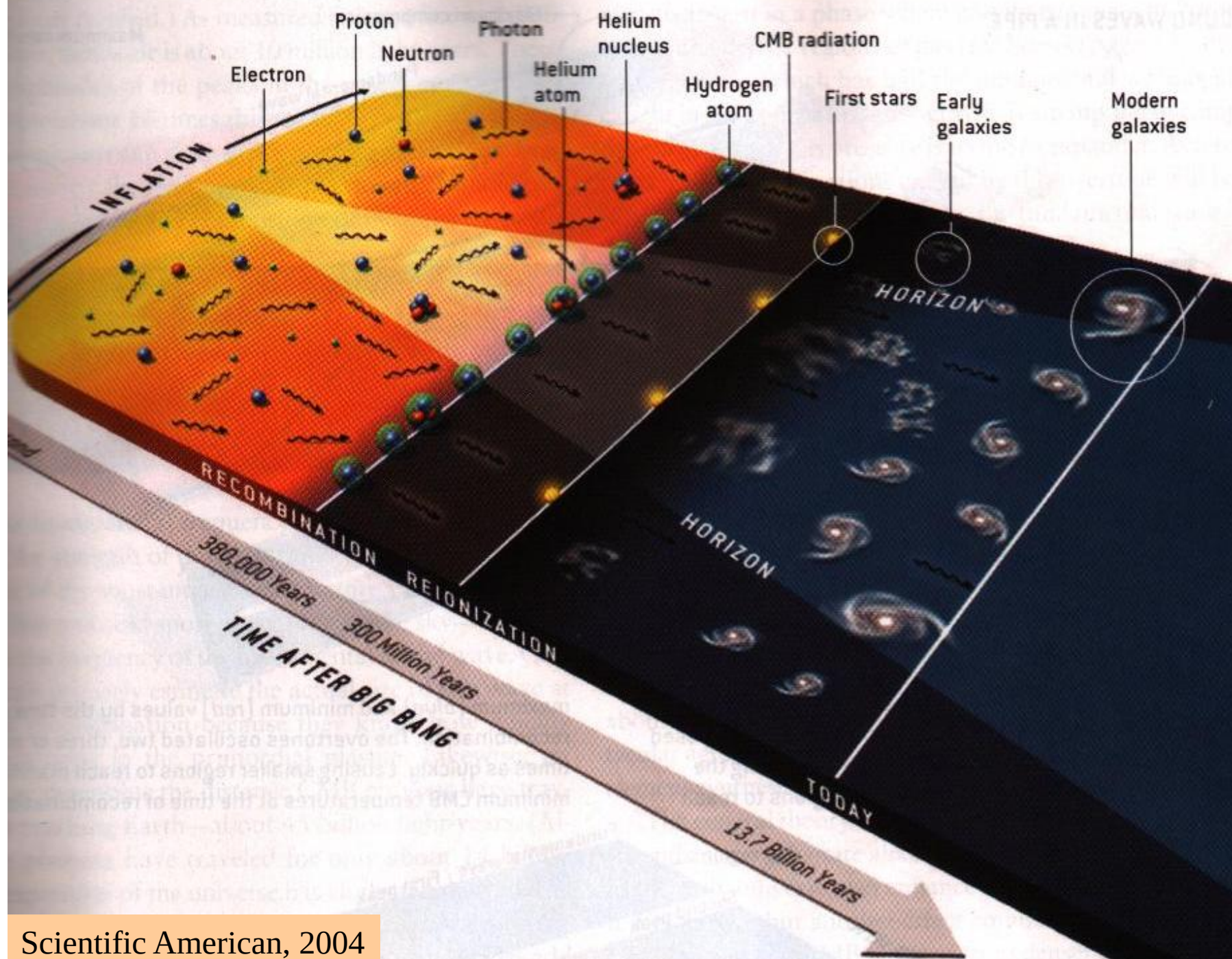
Physics

1948: Theory of Big Bang

**1963: Theory of Quarks, Quantum Chromodynamics
(Murray Gell-mann)**

The Theoretical Revolution

- **Big Bang model (1948)**
 - Quantum fluctuations in an infinitely small universe "created" the universe (space, time and matter) in a "big bang" (George Gamow)
 - Time slowly turned into spacetime giving rise to spatial dimensions
 - Spacetime started expanding (Alan Guth's "inflationary" model)



The Theoretical Revolution

- **Quarks (1963)**
 - **Protons and neutrons are made of 18 quarks (Murray Gell-Man) held together by gluons**
 - **Six leptons: the electron, the muon, the tau and their three neutrinos**
 - **Virtual particles (bosons) mediate the four fundamental forces: (photon, eight gluons, three weak bosons, graviton?)**
 - **Elementary particles: leptons, quarks and their anti-particles (total of 48) plus 12 bosons (total of 60)**

THE STANDARD MODEL

	Fermions			Bosons	
Quarks	u up	c charm	t top	γ photon	Force carriers
	d down	s strange	b bottom	Z Z boson	
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
	e electron	μ muon	τ tau	g gluon	

Higgs^{*}
boson

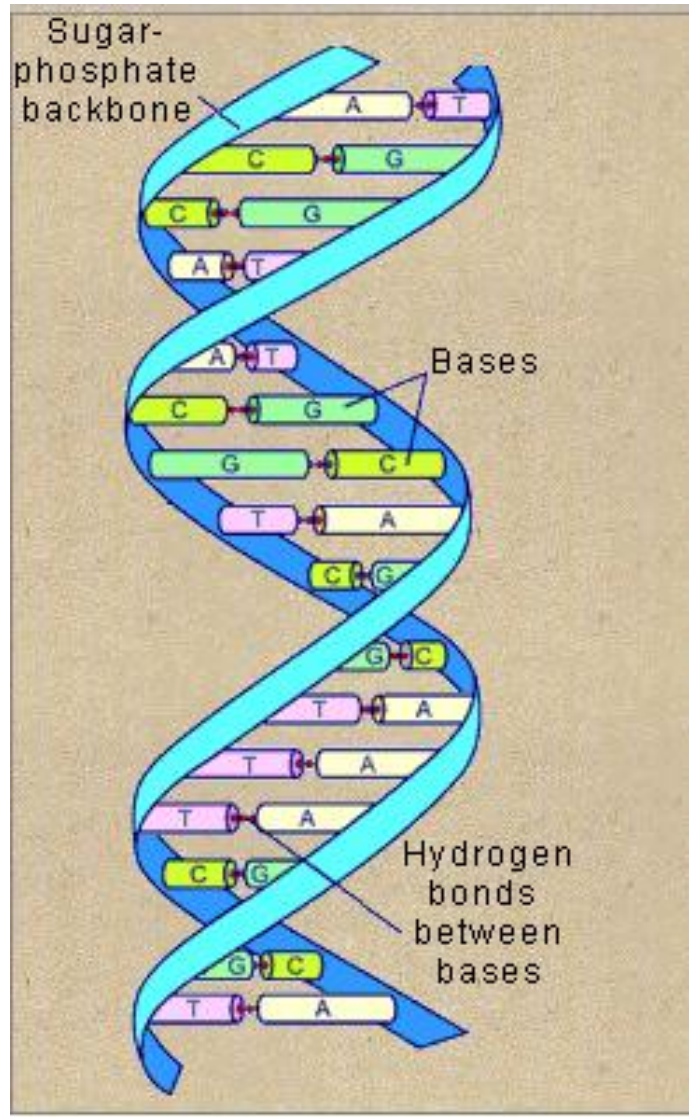
*Yet to be confirmed

Source: AAAS

The Theoretical Revolution

- **Physics/ Unsolved mysteries**
 - **Unification of Relativity and Quantum Theory**
 - **Higgs field**
 - **1998: Adam Riess discovers that the expansion of the universe is accelerating (dark energy)**
 - **2003: 95% of the universe is not accounted for**

The Genetic Revolution



The Genetic Revolution

Genetics

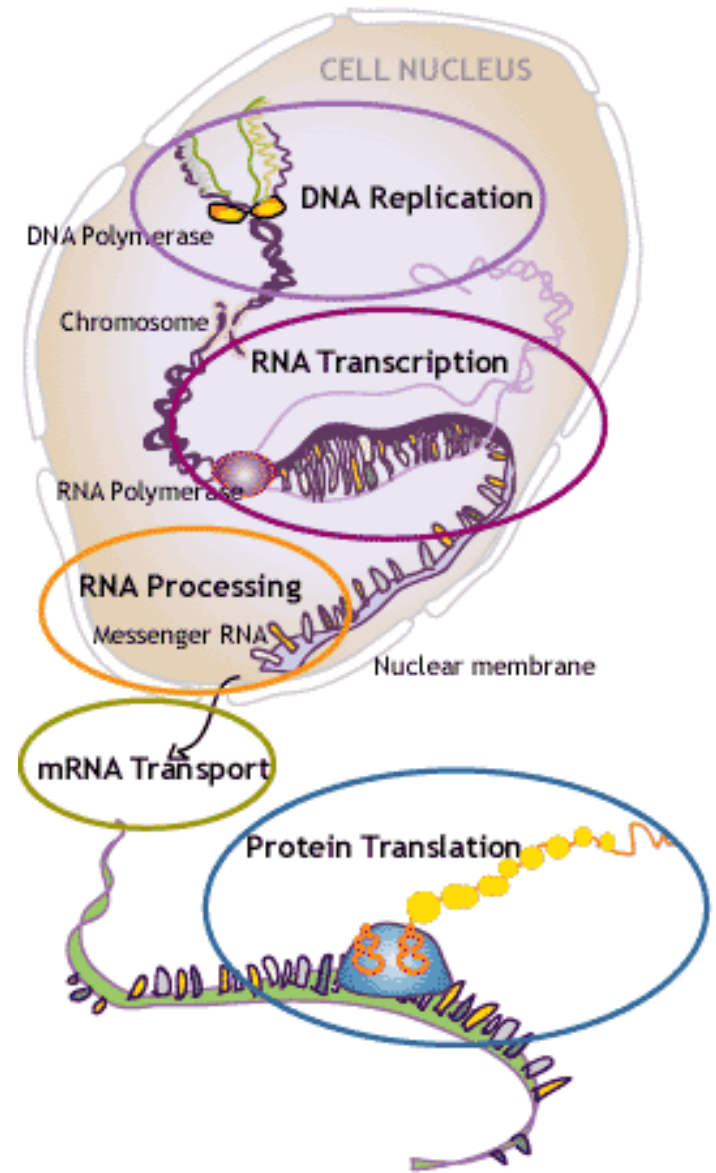
1944: Oswald Avery (DNA)

1953: Francis Crick and James Watson discover the double helix of the DNA

1960s: Translation of Four-letter Genetic Code Into Twenty-letter Language of Proteins

The Genetic Revolution

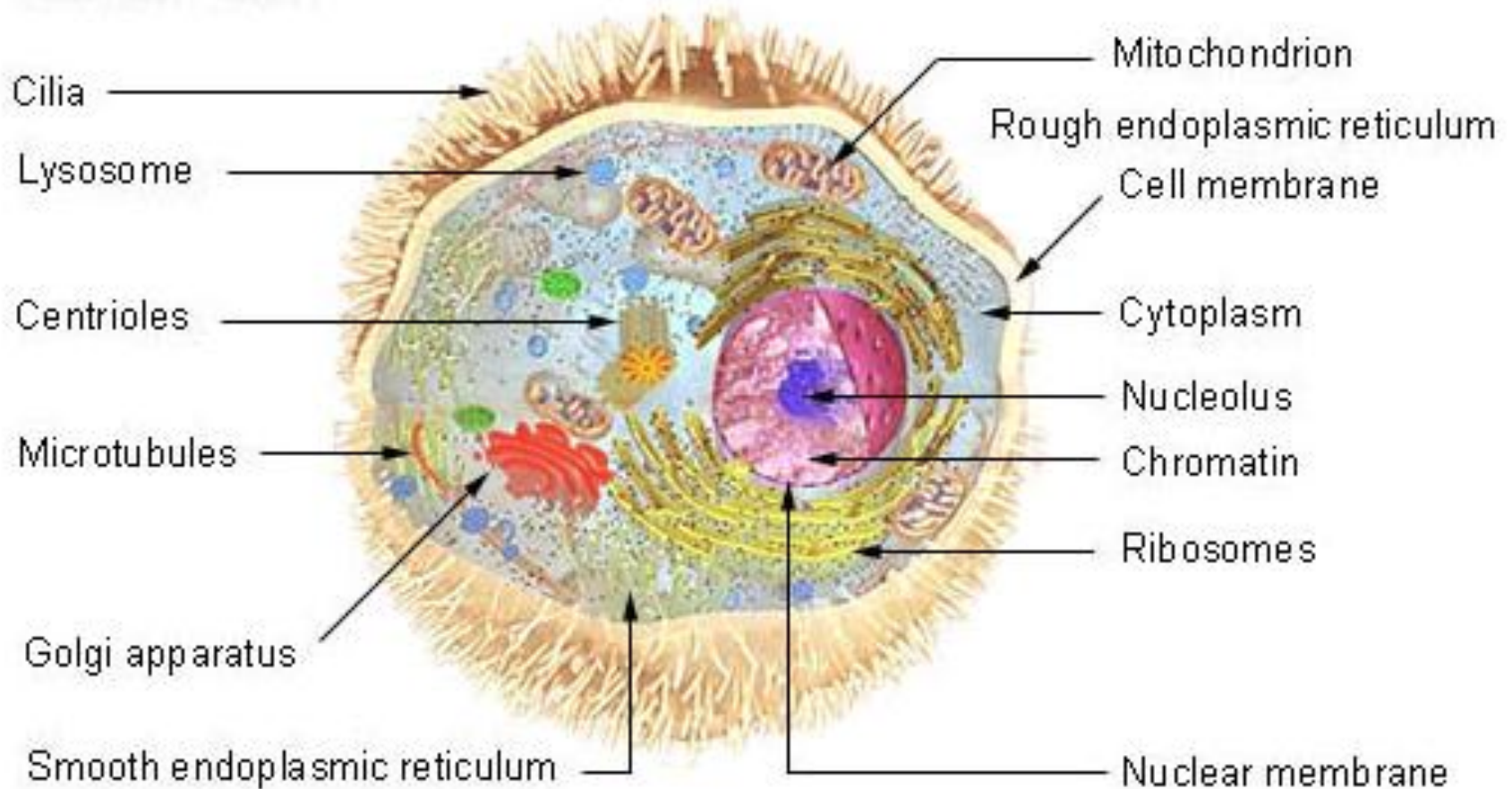
DNA, RNA, Proteins



The Genetic Revolution

The cell

Cell Structure



The Genetic Revolution

- **Genetics**
 - **1988: first genetically engineered animal, a mouse (Harvard Univ)**
 - **1990: the Human Genome Project is launched**
 - **1994: the first genetically engineered vegetable (Flavr Savr tomato) is introduced**
 - **1997: British biologist Ian Wilmut clones the first mammal, a sheep, Dolly (dies in 2003)**
 - **2002: American scientists synthesize a live virus from chemicals**
 - **2003: the Human Genome Project is completed, having identified the 19,599 +2,188 genes in human DNA**

The Genetic Revolution

- **Genetics/Unsolved mysteries**
 - The origin of life
 - The origin of species
 - 95% of the genome is junk