united nations
educational, scientific
and cultural
organization

international atomic
energy agency

the
abdus salam
international centre for theoretical physics

ICTP 40th Anniversary

H4.SMR/1574-2

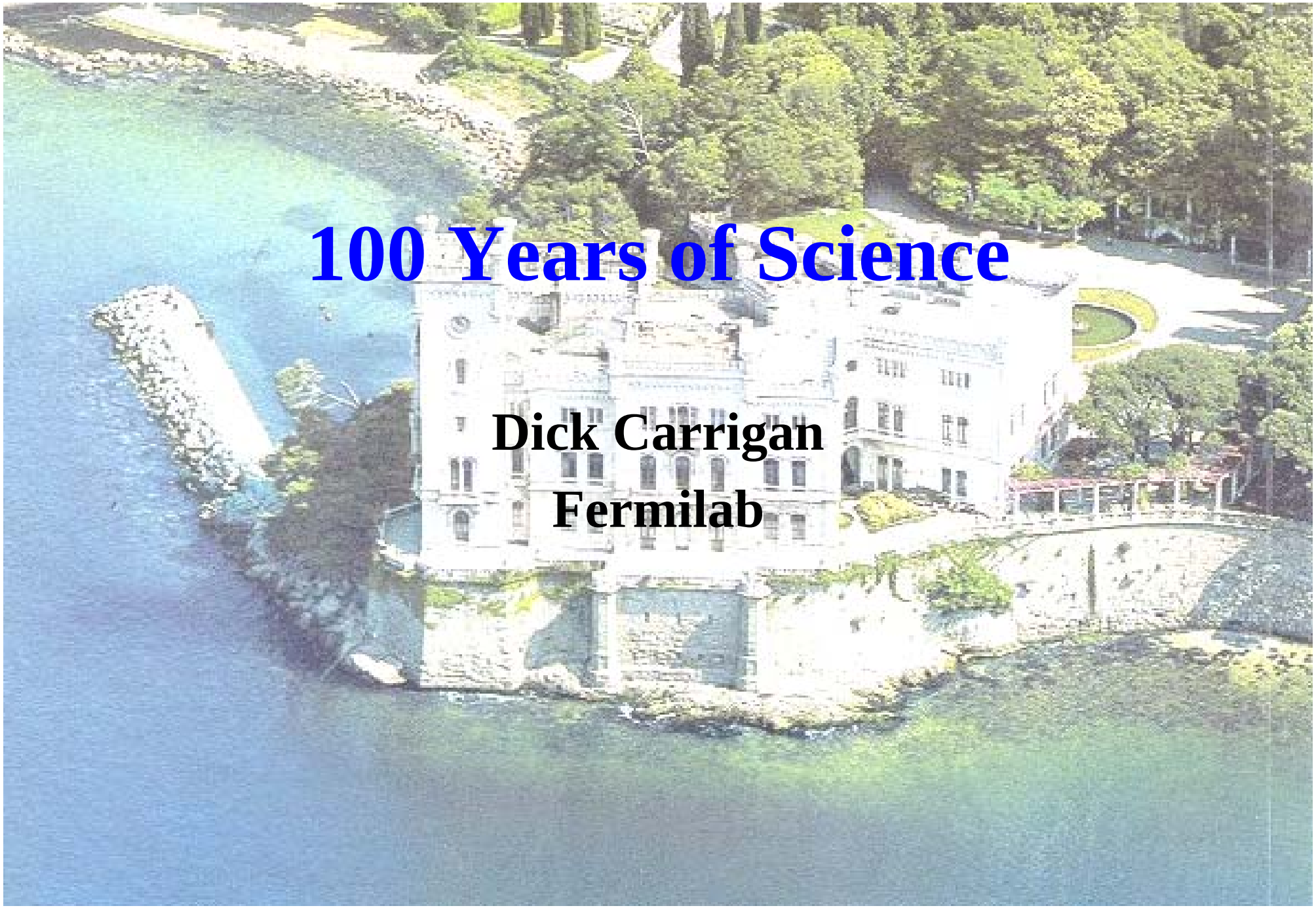
"VII School on Non-Accelerator Astroparticle Physics"

26 July - 6 August 2004

100 Years of Science

R. Carrigan

Fermi National Accelerator Laboratory
Batavia, U.S.A.



100 Years of Science

Dick Carrigan
Fermilab

Nancy Jean Carrigan

can I unweave the gauzy fabric of stars?

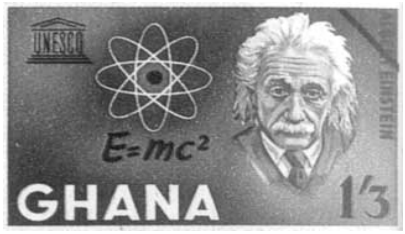
can I untangle the matted carpet of earth?

"Astrophysics and the Ant" Acrylic on Linen Nancy Jean Carrigan © 2000

Contact Nancy at: carrigans2@aol.com

What 100 years are we talking about?

Maxwell 1873 to 1973 – no fun



Planck – 1900,

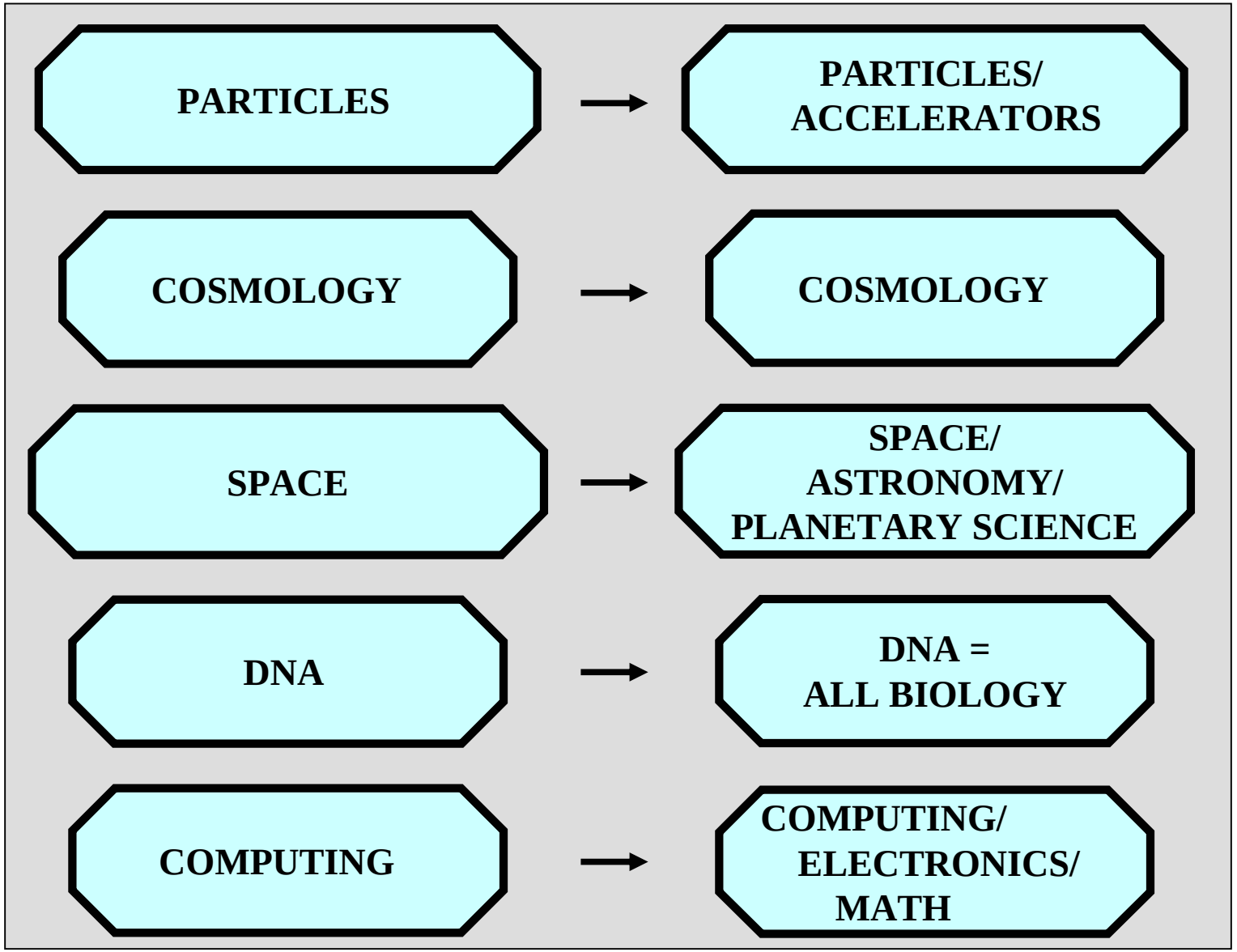
Einstein 1905 but that's last century

Schrödinger 1926

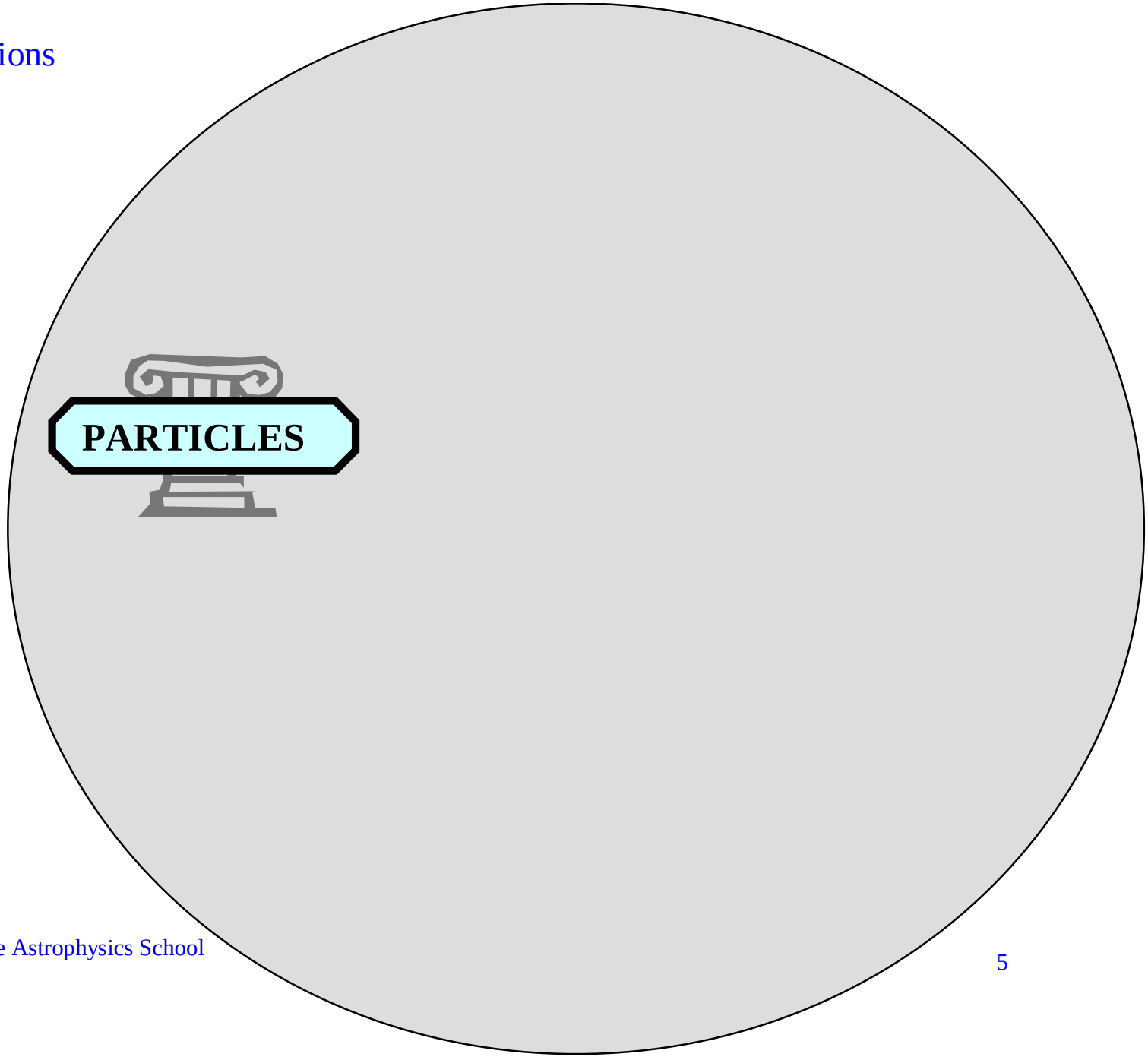
or maybe 1944 "What is Life?"

Take start as **1944** to get 1950s explosion: rocket science, mesons, DNA, BB

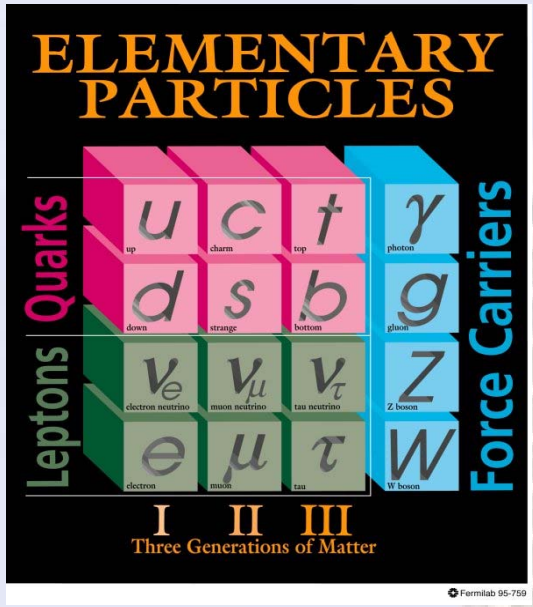
Definitions

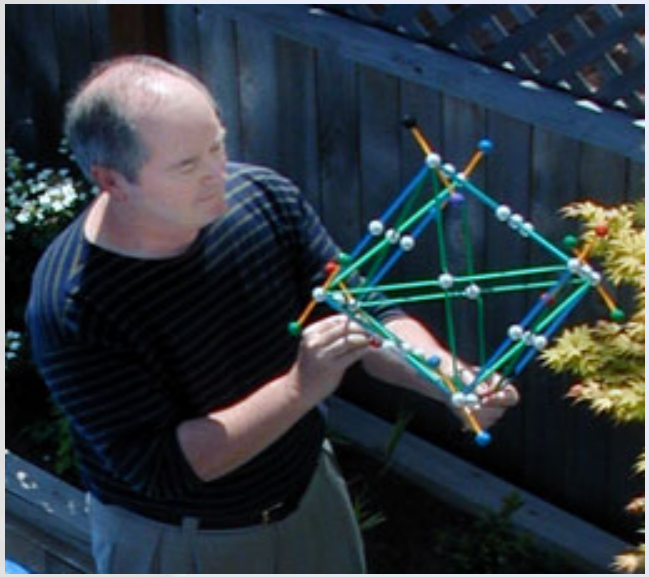


Technical revolutions
of the last
half century



Particle physics





Chronology – mostly experimental discoveries

1897	Using a cathode ray tube Thomson discovers the electron at the Cavendish
1931	Anderson discovers the positron at Cal Tech
1934	Fermi develops theory of beta decay
1937	Neddermeyer and Anderson discover the muon in a cosmic-ray experiment
1951	First observation of strange particles in cosmic-ray experiments.
1955	Segre and Chamberlain discover the antiproton at Berkeley.
1956	Cowan and Reines detect the first neutrino at Savannah River.
1956	Gell-Mann explains kaon lifetime with the strangeness
1964	At Brookhaven Cronin and Fitch find kaons violate CP symmetry
1974	Physicists at SLAC and BNL independently discover charm quark
1977	The upsilon, a particle containing a bottom quark, is discovered at Fermilab
1979	Gluon observed at DESY.
1983	W and Z bosons observed at CERN
1995	CDF and D0 discover top quark at Fermilab

The future for particle physics

Some of Quigg's April 28, 04 "Questions for the Future"

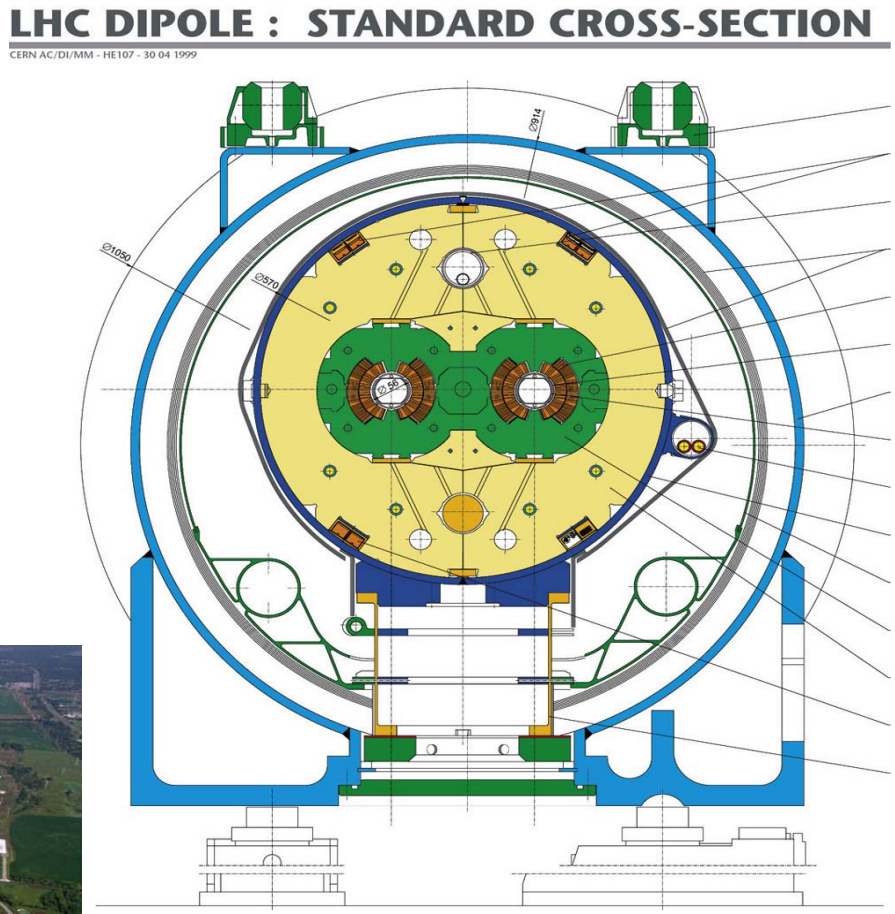
1. Are quarks and leptons elementary?
2. What is the relationship of quarks to leptons?
3. Are there right-handed weak interactions?
4. Are there new quarks and leptons?
5. Are there new gauge interactions linking quarks and leptons?
6. What is the relationship of left-handed & right-handed particles?
7. What is the nature of the right-handed neutrino?
8. What is the nature of the new force that hides electroweak symmetry?
9. Are there different kinds of matter? Of energy?
10. Are there new forces of a novel kind?
11. What do generations mean? Is there a family symmetry?
12. What makes a top quark a top quark and an electron an electron?
13. What is the (grand) unifying symmetry?

From Quigg http://www.fis.puc.cl/~rlineros/research/cdmexico/talks/BeyondSM/BSM1.pdf

Accelerators

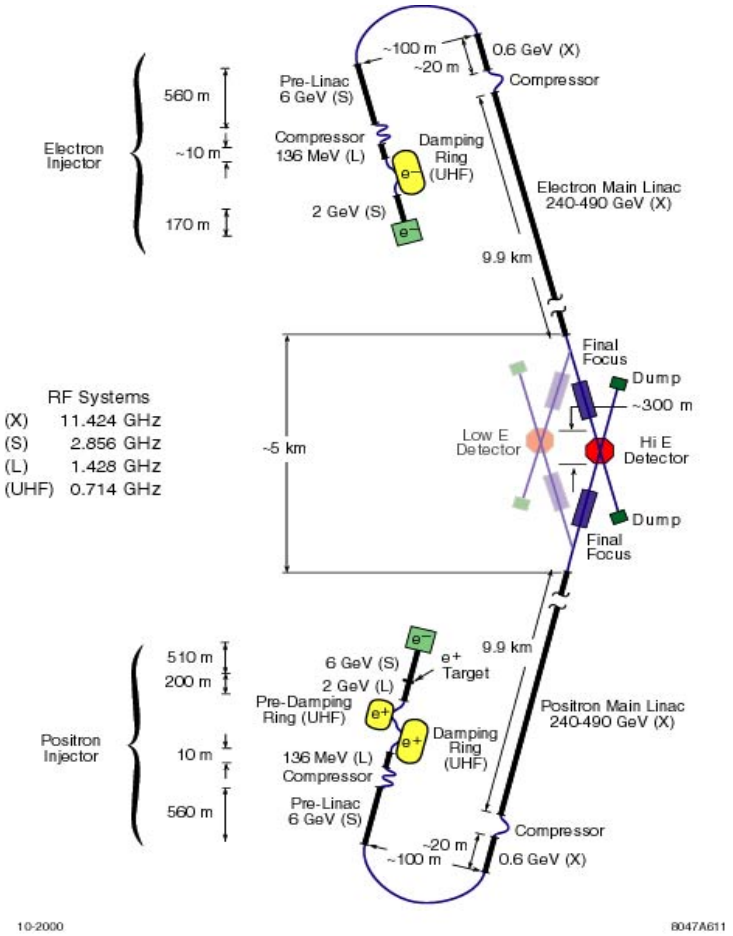
Fermi at Chicago

Synchrocyclotron - 1951



Accelerators beyond LHC – everything has problems

NLC

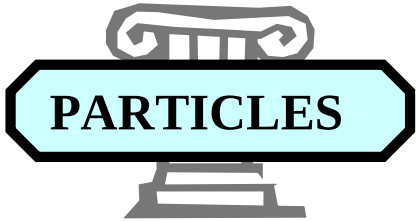


or Plasma wake field acceleration

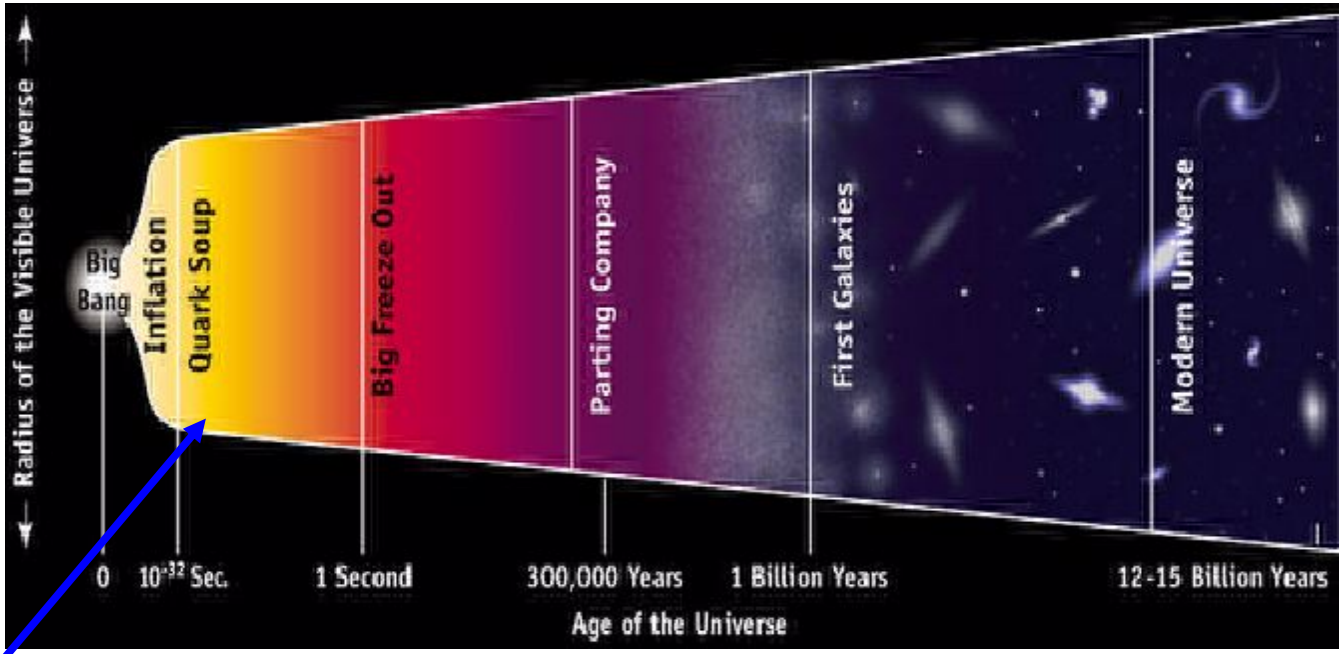
$G = 0.96(n_0)^{1/2}$ (V/cm) n_0 is electron density

RF cavity	0.0005 GV/cm
gaseous plasma	1 GV/cm
solid state plasma	100 GV/cm

Technical revolutions
of the last
half century



The Big Bang

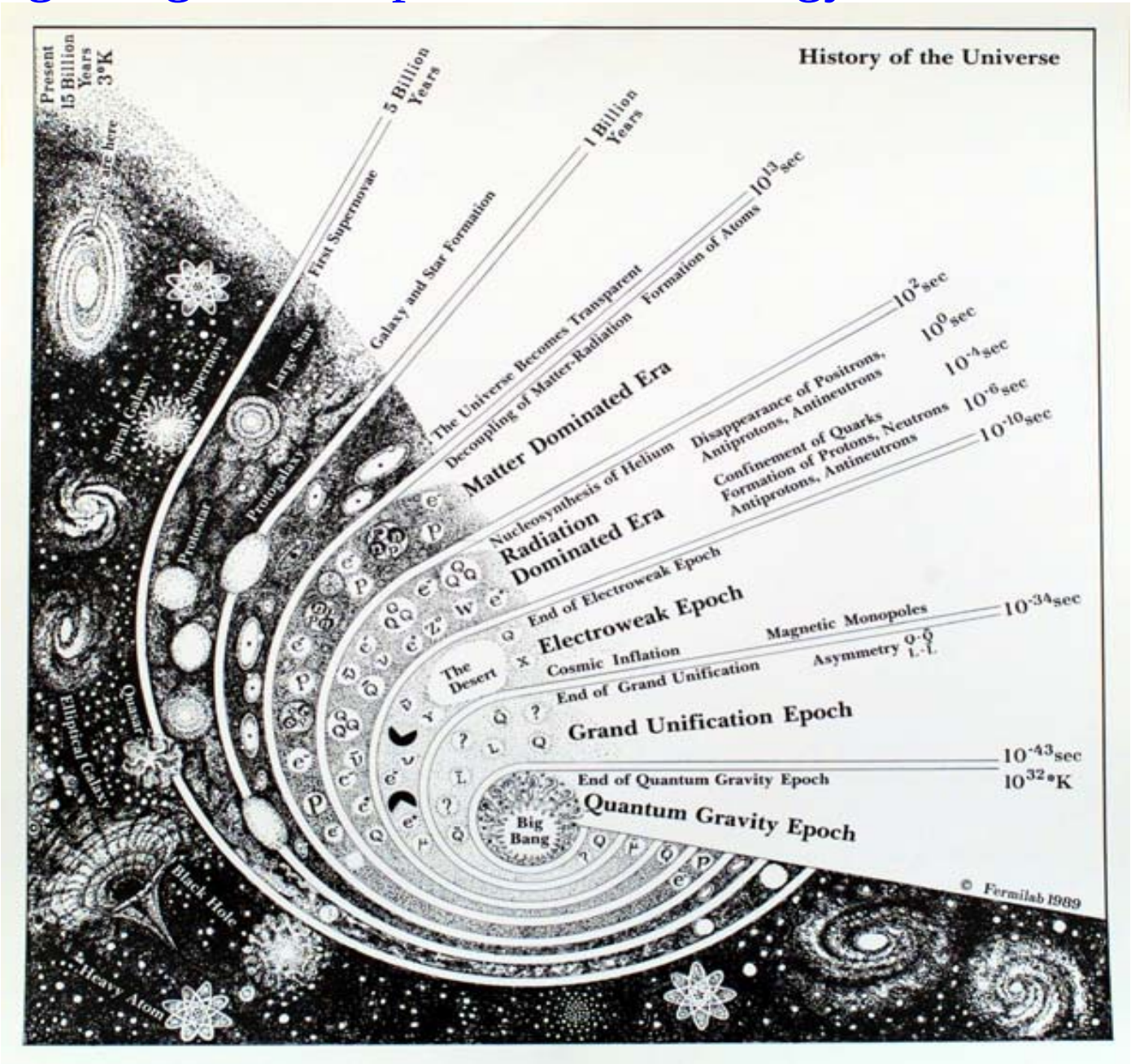


From http://ist-socrates.berkeley.edu/~phy39/stellarE/starshine.html

PARTICLE PHYSICS

Big bang explained what came afterwards
but not the big bang itself

The Big Bang and the particle /cosmology connection



The next forty years in particle cosmology

Even more precise WMAP-type observations

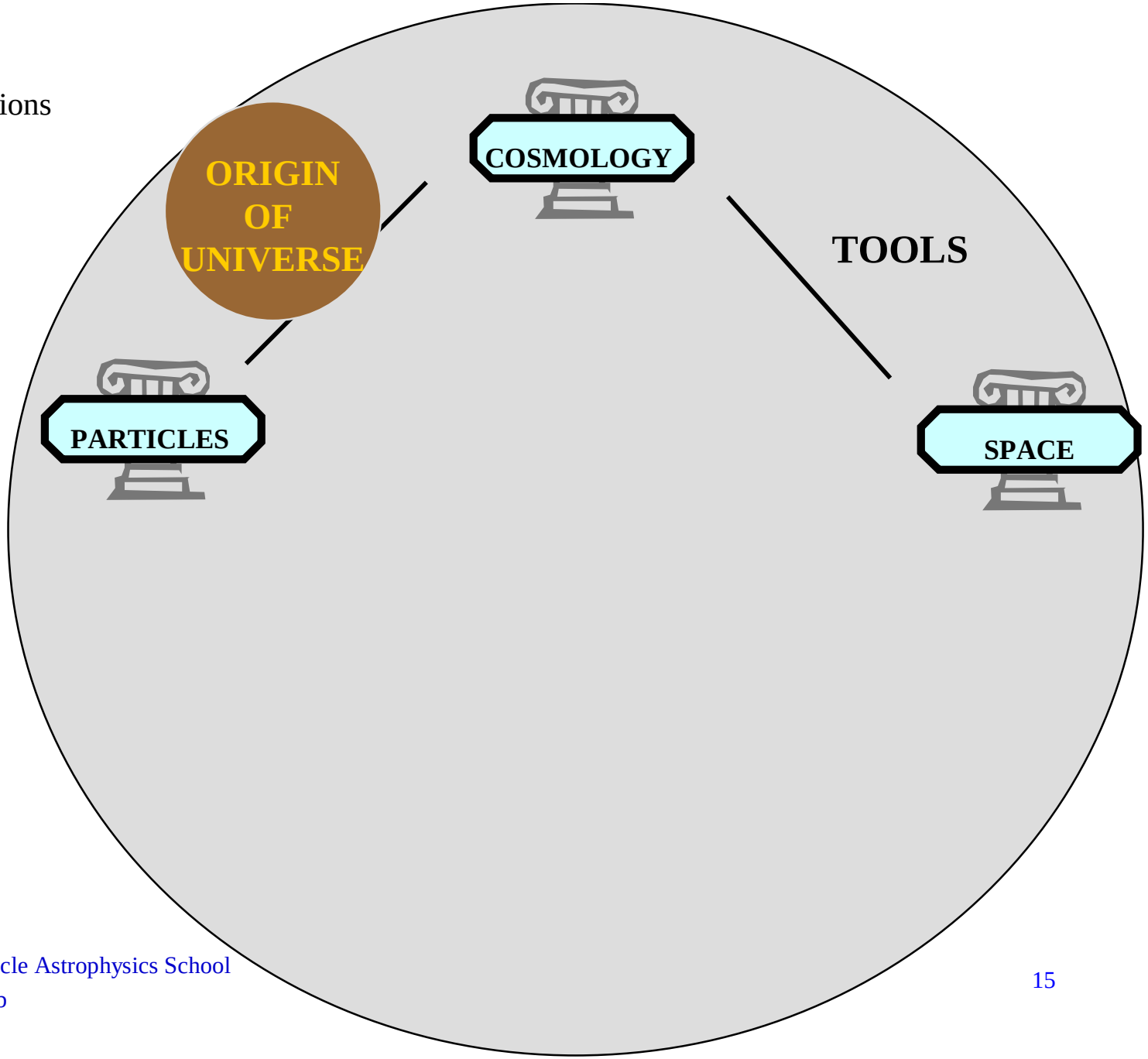
Dark matter and dark energy investigations continue

Gravity waves

The fabric of space

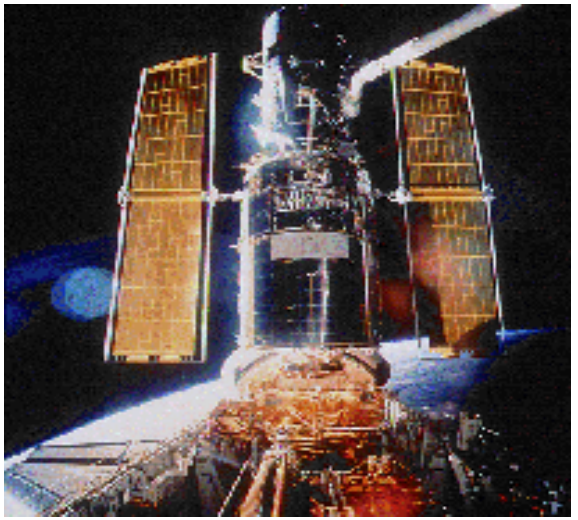
Particle physics finds the key?

Technical revolutions
of the last
half century



History of Space and Astronomy

V2 at White Sands
The birth of real rockets at Penemunde 1930s

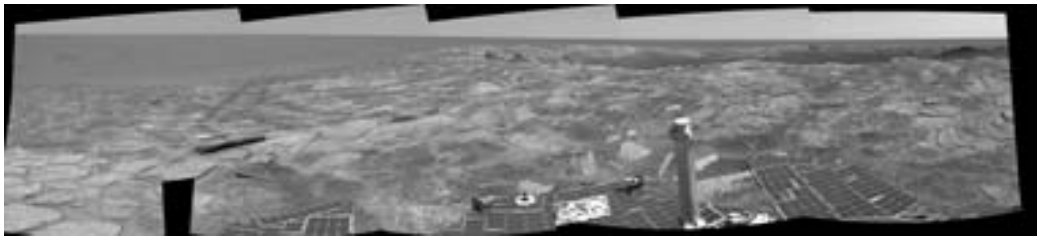


First Hubble service mission in 1993

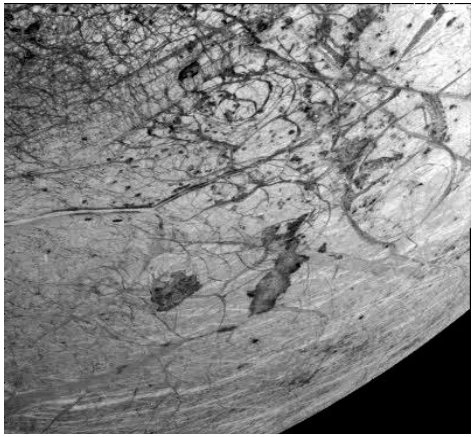
Harrison Schmitt on the Moon. NASA photo (1972)

First and only scientist on moon

NASA Rover robot on Mars 2004 looking for water

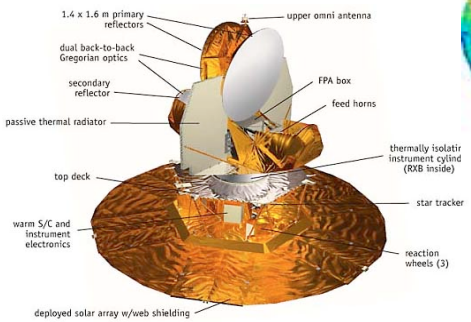


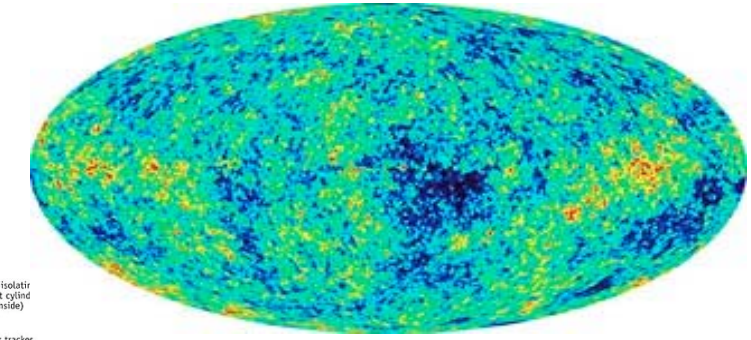
Space and Astronomy



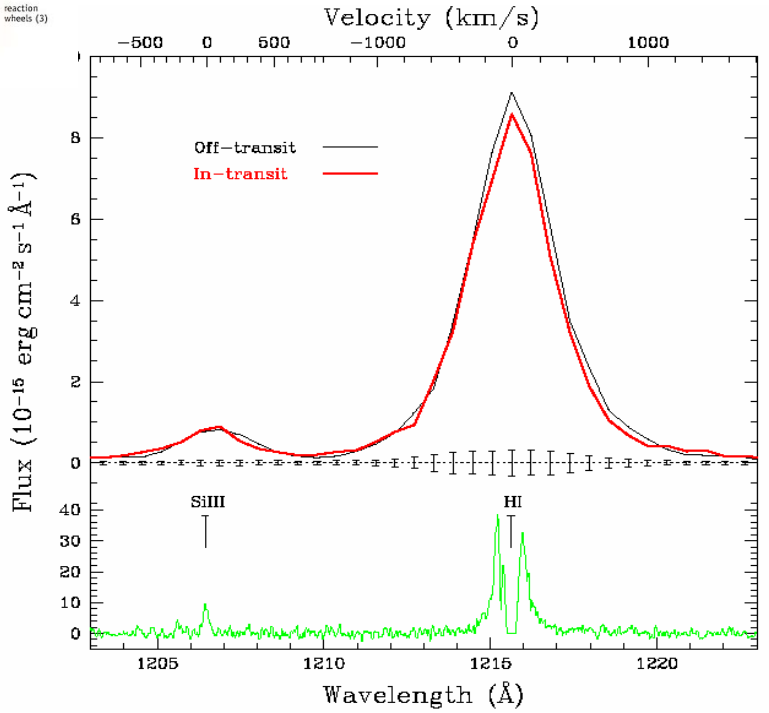
Icy surface of Europa
– an abode for life?

WMAP

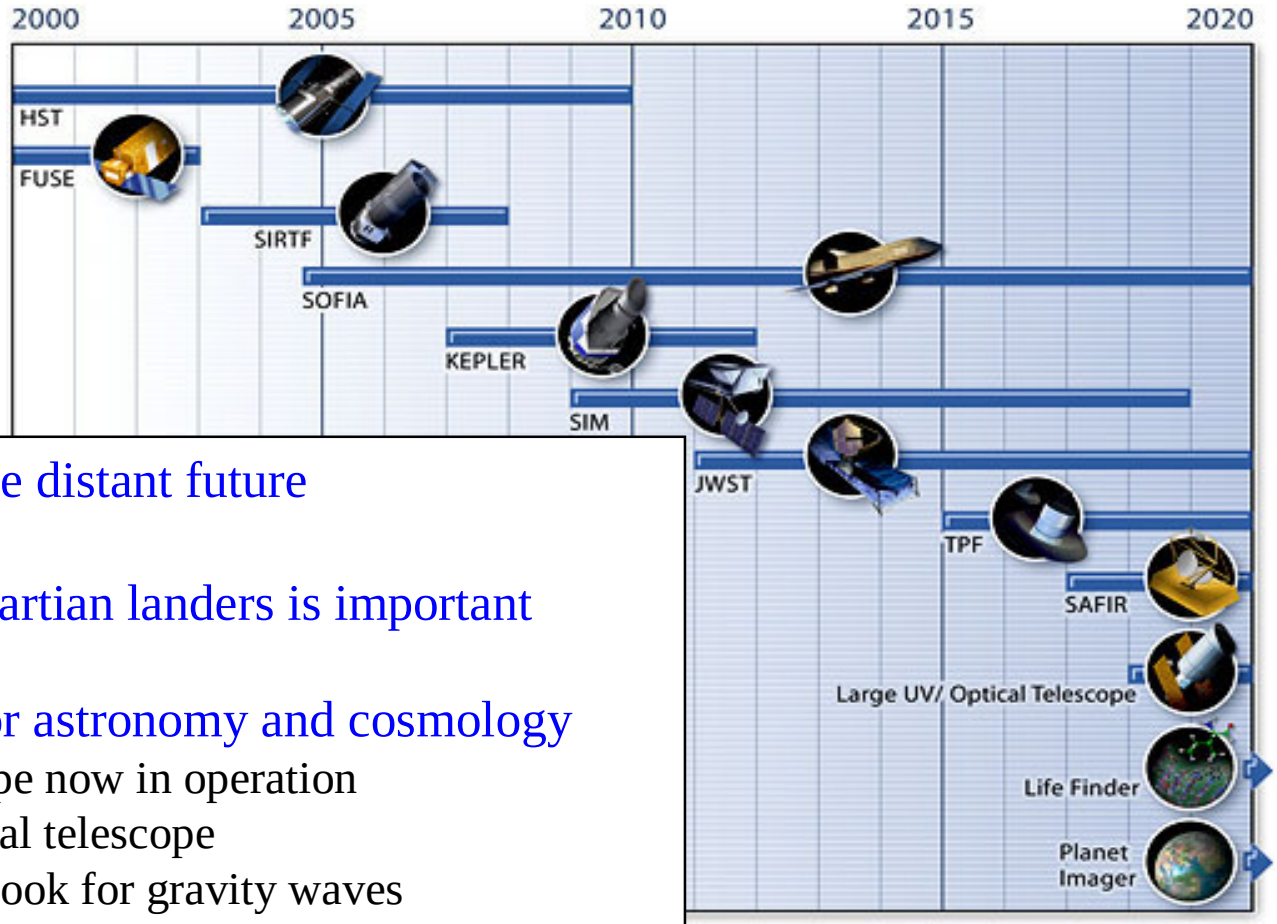




O and C in atmosphere of extrasolar planet HD209458 observed with the STIS spectrograph on board Hubble (2004)



The future of space



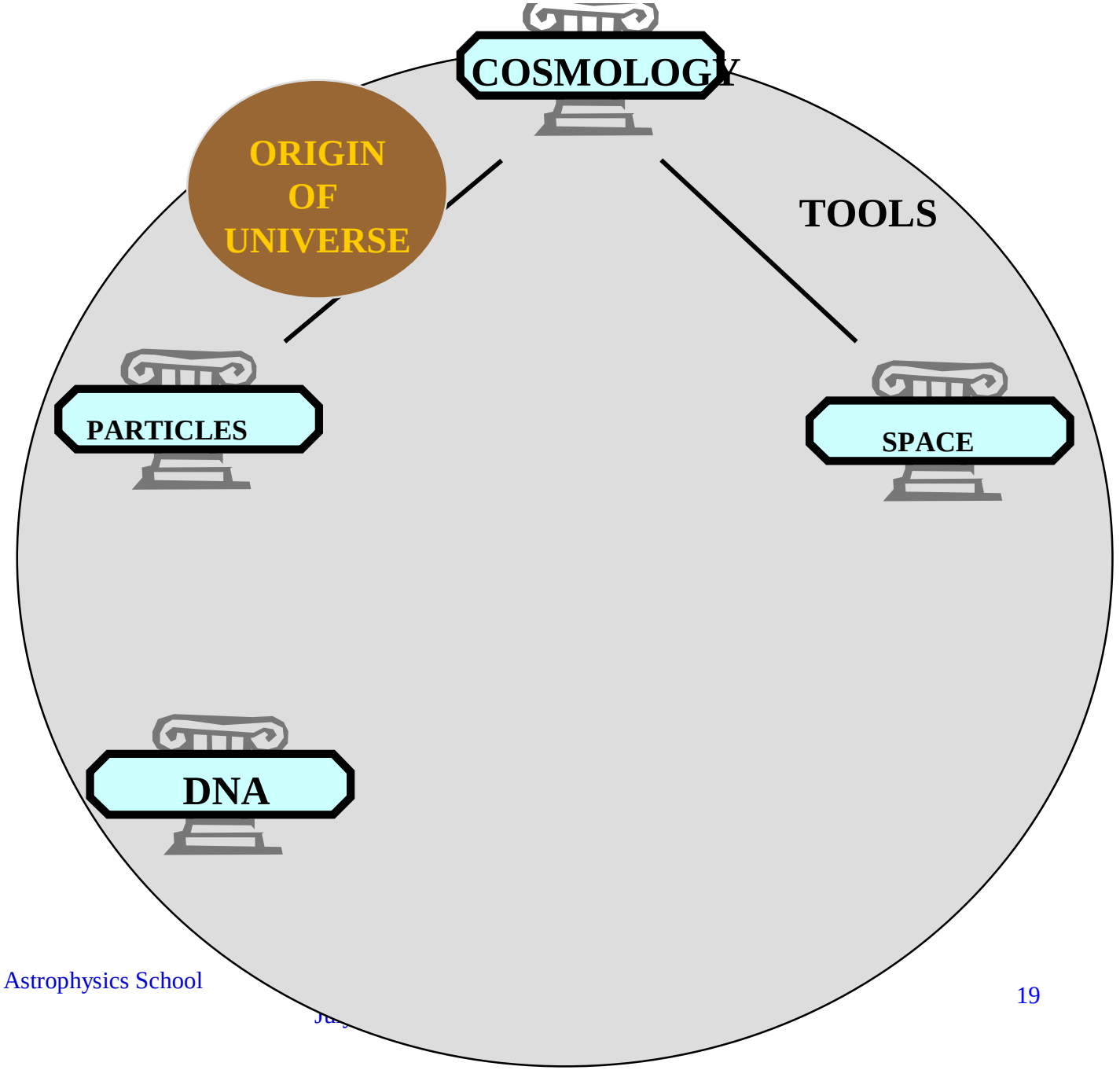
Man has a role but for the distant future

Robotics ala the 2004 Martian landers is important

Enormous importance for astronomy and cosmology

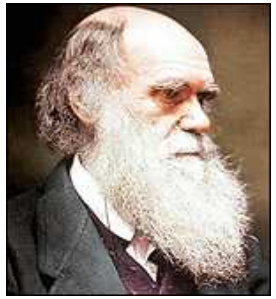
- Spitzer Infrared Telescope now in operation
- James Webb 6.5 m optical telescope
- LISA – constellation to look for gravity waves
- SIM – interferometry to look for exosolar planets
- Kepler - exosolar planets by transit

Technical revolutions of the last half century

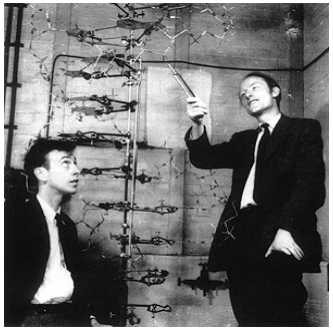


Dirt, Darwin, and DNA

The evolution of the geology of earth including impacts and the atmosphere drives the environments



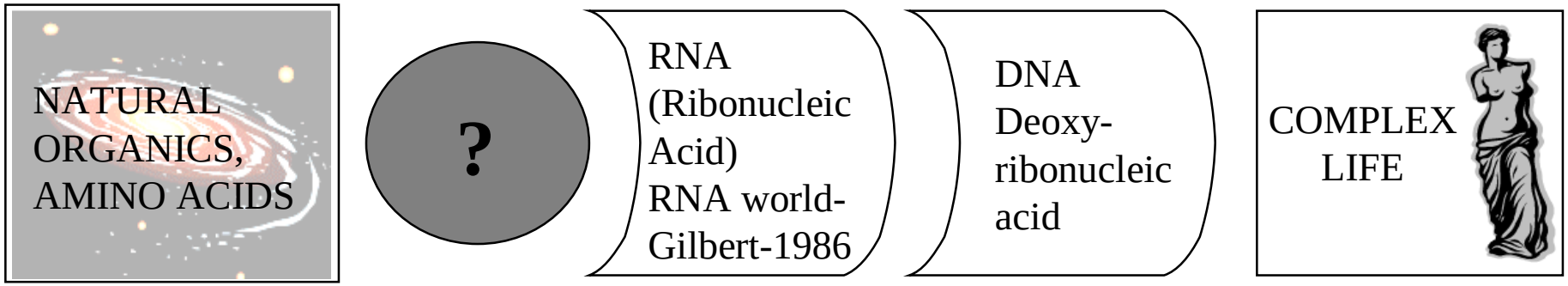
Survival of the Fittest for different environments explains evolution



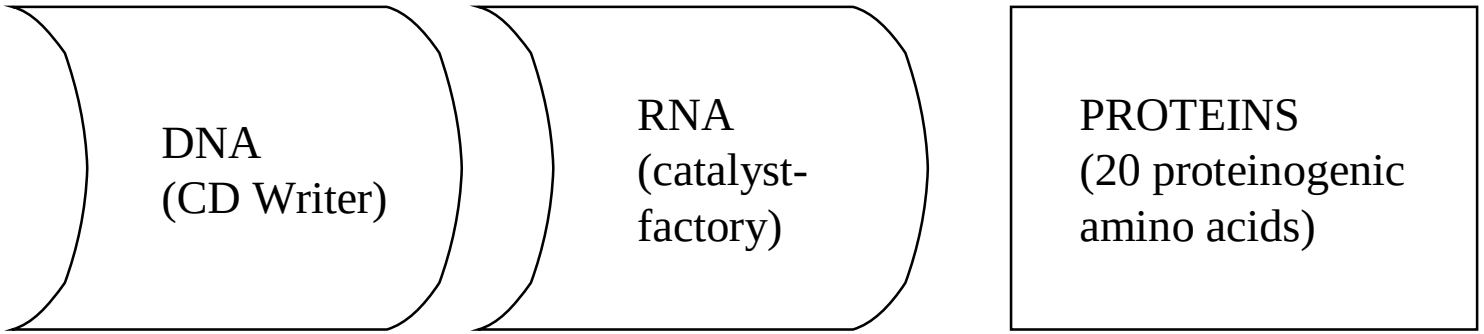
DNA (~1953) Proteins have 20 amino acids. There are 4 bases in DNA (adenine[A], guanine[G], cytosine[C], thymine[T]). Combinations are AT (2 hydrogen bonds) and GC (three hydrogen bonds). The number of bits/base pair is 4.32/3= 1.44 bits/bp = ln_2(20)/3 where 3 is the number of base pairs in a codon (a triplet of base pairs). 600 Daltons for mass of a base pair with backbone and bonds. Human genome-3 billion DNA base pairs, actual information content is on the order of 0.05 Gbytes because of junk DNA. Point- lots of information per mass.

Big Bang of Biology

ORIGIN OF LIFE

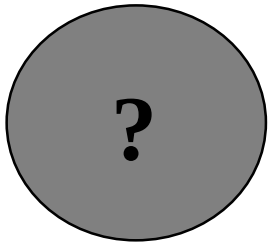


GENETIC INFORMATION FLOW



Origin of life

T



Don’t know. Chirality may be a clue.

De Duve argues RNA by chance is implausible.

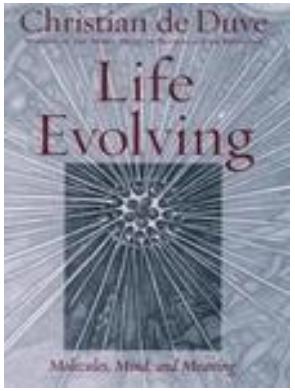
Needs a complex chemical environment.

Some argue catalysts are needed

but maybe not for peptides.

Maybe clays help.

Maybe a natural selection for molecules.



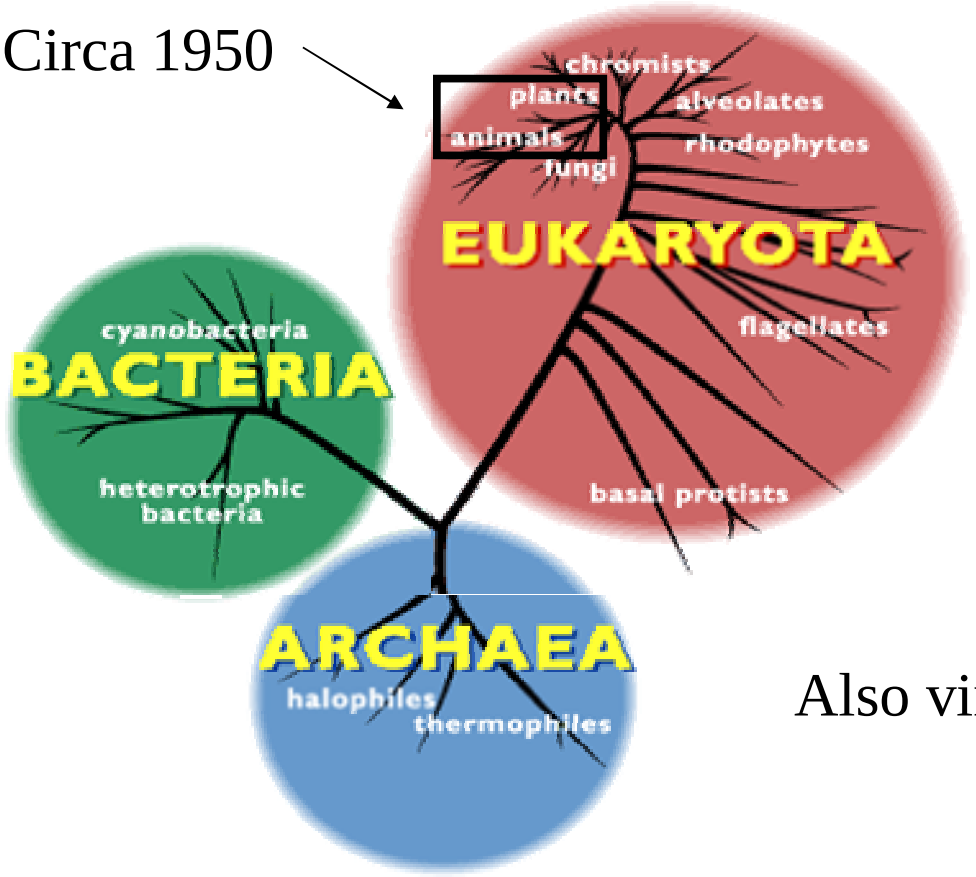
History of life on earth – the first billion years:

- Birth of the Solar System 4.6 billion years ago. Hot (molten) atmosphere of H_2O, CO_2 and CO, N_2 and H_2 until 0.1 Gyr
- Rain 0.1 to 0.3 Gyr, rocky crust 0.2 to 0.4 Gyr.
- Biologically processed carbon 1 Gyr (self-replicating, carbon-based microbial life)
- not much free oxygen - anaerobic life
- And then photosynthesis began to produce oxygen

See :Astrobiology:The Quest for the Conditions of Life- Gerda Horneck Christa Baumstark-Khan (Eds.)

Tree of life – not your parents biology

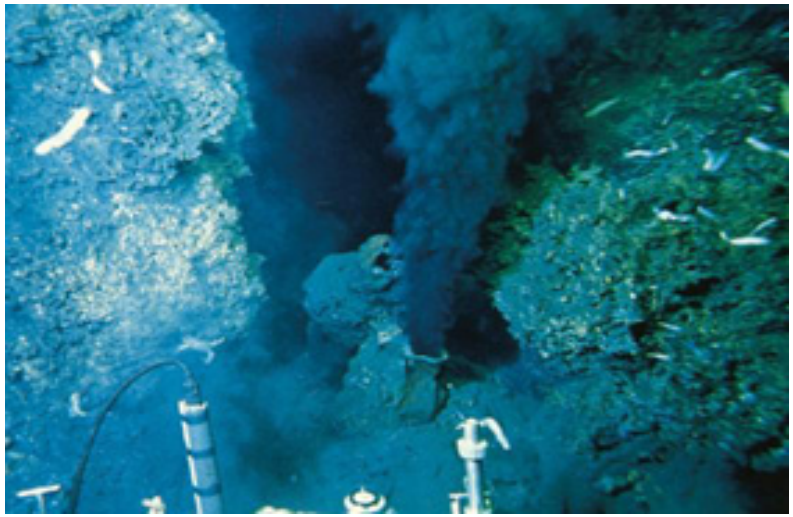
Circa 1950

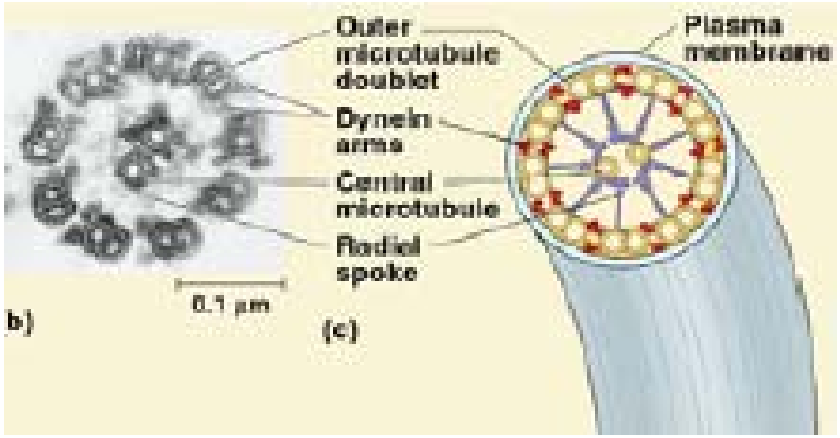


Also viruses

From http://www.ucmp.berkeley.edu/alllife/threedomains.html

Speeding up evolution





Extremophiles

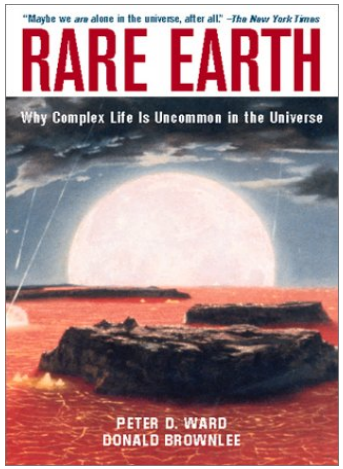
- Thermophiles-deep hydrothermal vents along mid ocean rifts - volcanic vents or "black smokers"
- Salty (halophiles)
- Cold, dry, high radiation, ...

Symbiosis-Margulies-speeds up

The astrobiology link

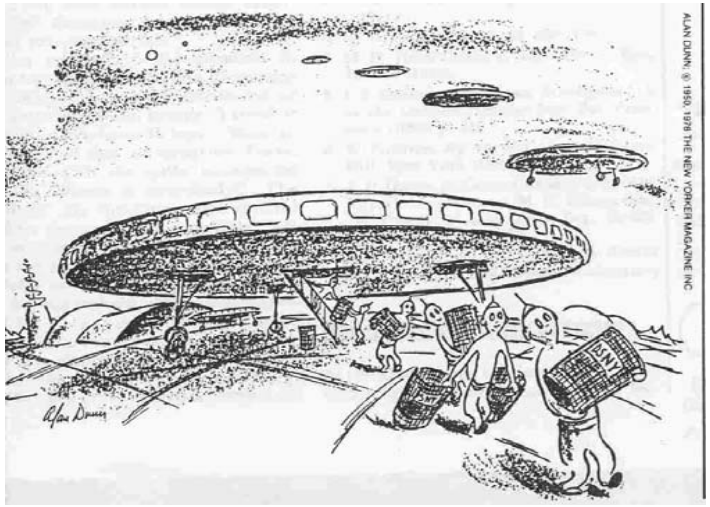
Extraterrestrial signatures of life – the next fifty years

- Meteors – Antartic collection
- Planets and satellites (Mars, Europa) - Rovers
- Atmospheres of extrasolar planets – spectroscopy, interferometry
- Planetary and galactic habitable zones

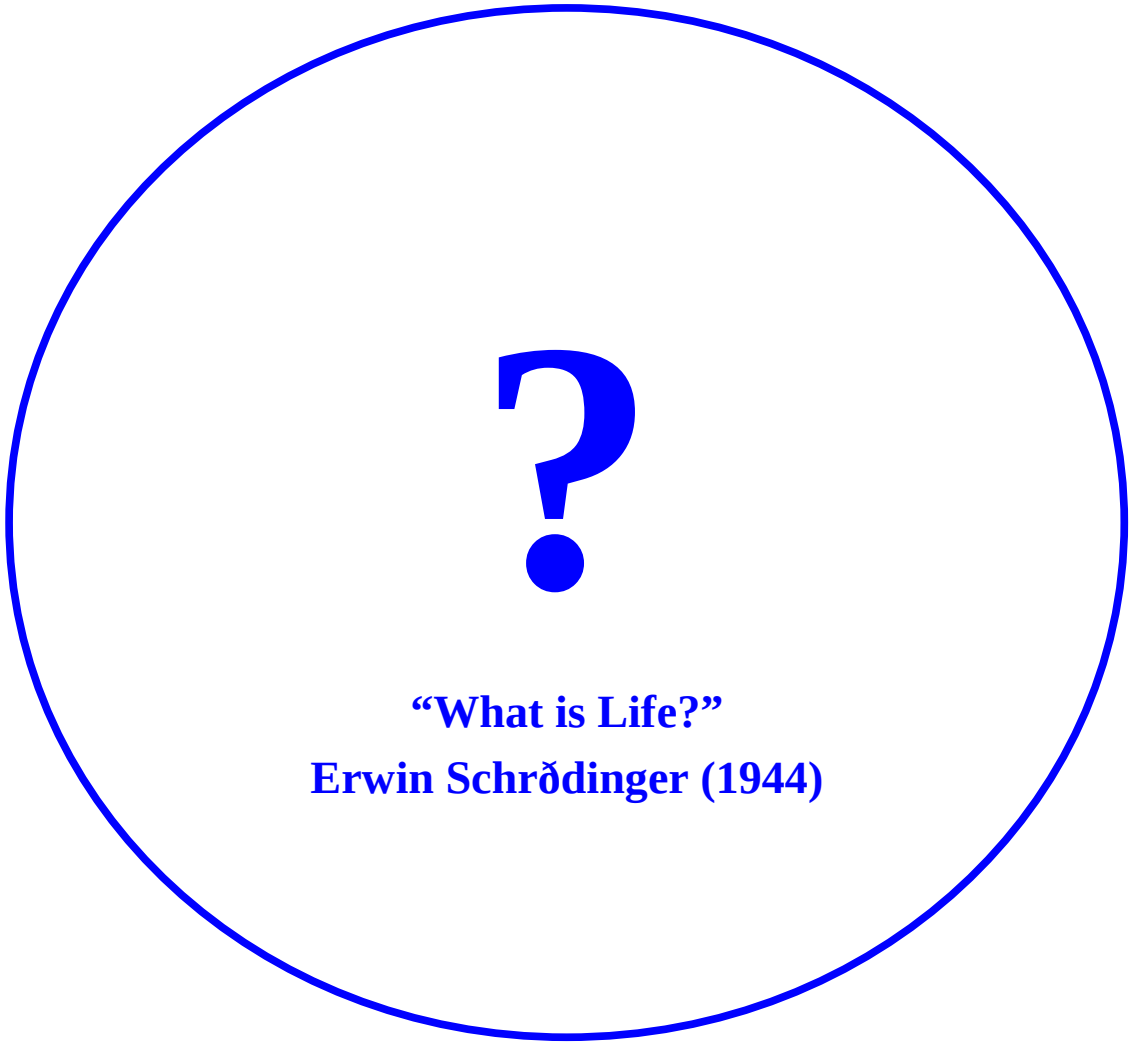


Extraterrestrial intelligence – SETI

- how frequent (if at all)?
- the Fermi question or paradox



From the New Yorker 20 May 1950,
Physics Today August 1985


?
“What is Life?”
Erwin Schrðdinger (1944)

Anthropic Principle – a perfect universe for us

Brandon Carter (73)

Cosmology and the standard model

James D. Bjorken*

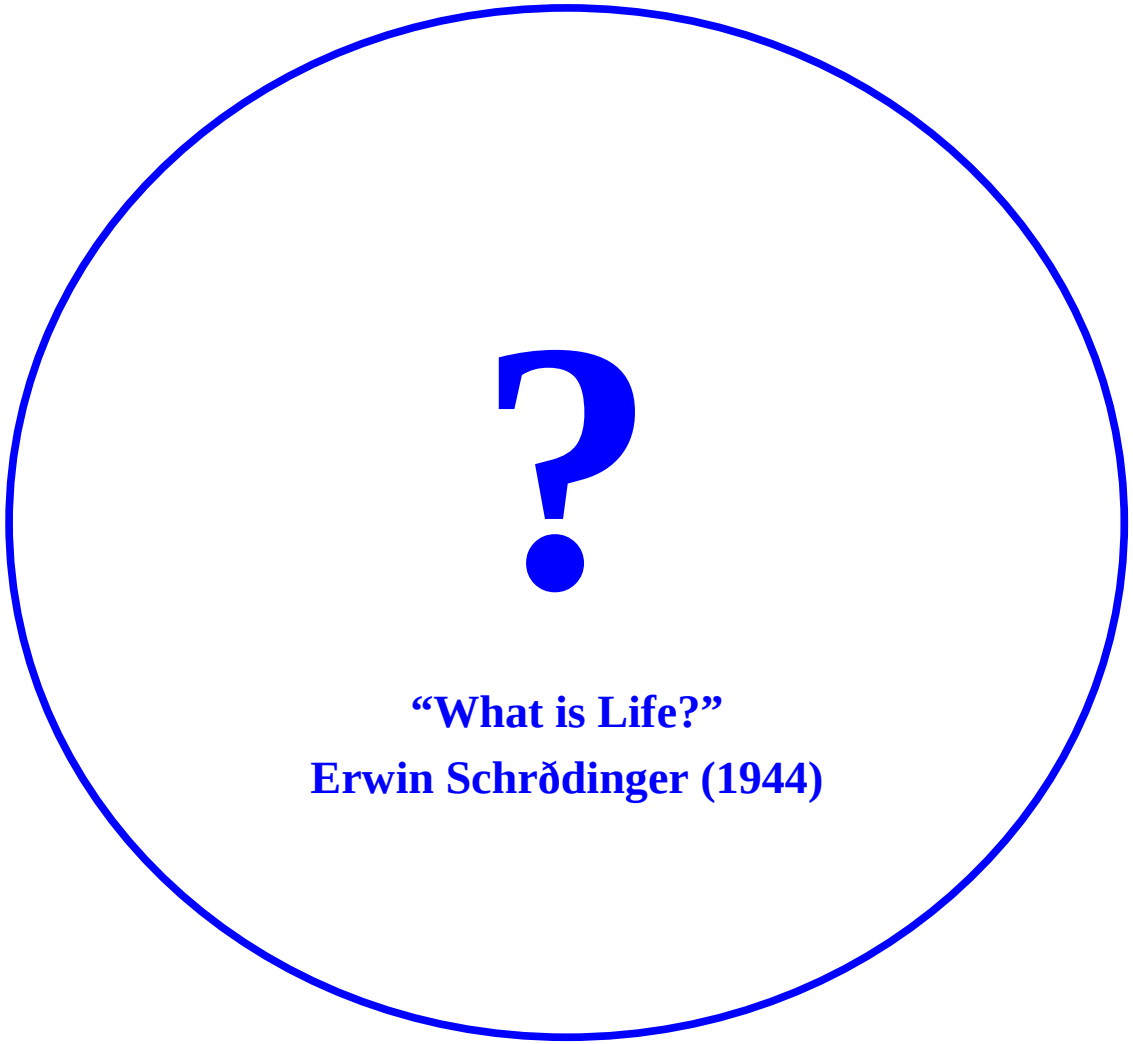
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309

Received 21 October 2002; published 26 February 2003

PHYSICAL REVIEW D **67**, 043508 (2003)

"… it is well known, … that other properties of our universe are very finely tuned and will only exist over a quite small bandwidth. We shall pay special attention to such ''anthropic'' constraints, as discussed for example in the book by Barrow and Tipler and will be interested in the bandwidth in *R* for which they are satisfied."

…. Crucial to the properties of nuclear and atomic matter are the values of the fine-structure constant ~here constrained to a reasonable range of values, the ratio of electron to proton mass, the ratio of pion to proton mass, and the neutron proton mass difference ….Finally, we may consider the mechanism for producing carbon in stars. This depends upon the existence of the anthropically famous **triple-alpha reaction** …with the resonance in ^{12}C predicted by Hoyle … together with the absence of a crucial level in ^{16}O."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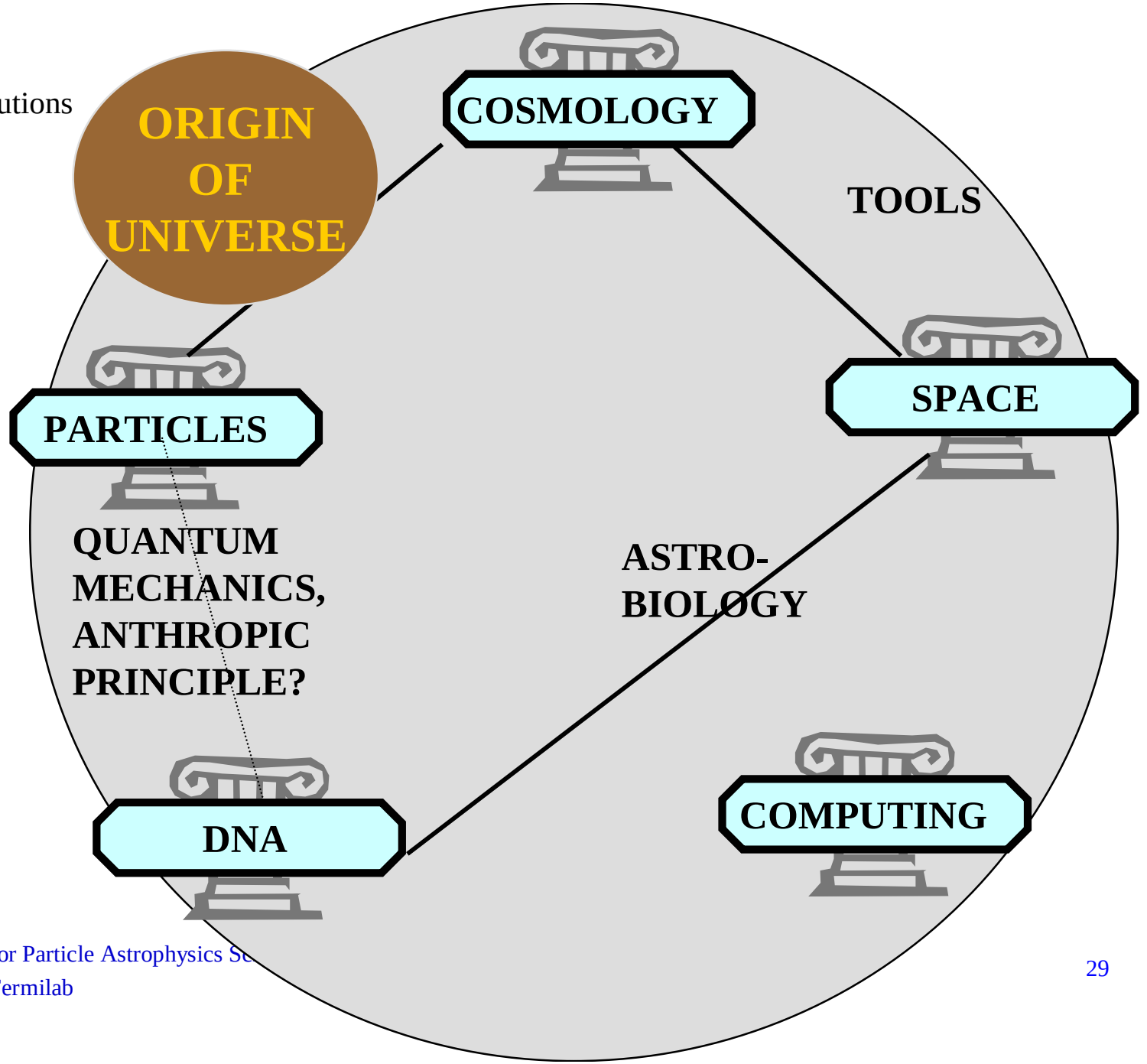
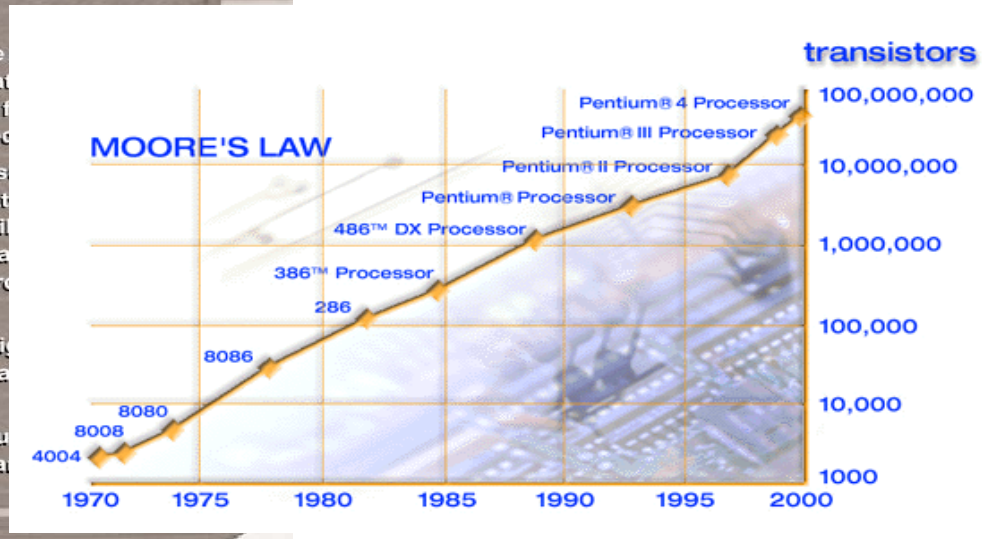
Technical revolutions of the last half century



Computing

This computer – 18.5 Gbytes, 650 MHz.

Tim Berners-Lee



http://www.intel.com/research/silicon/mooreslaw.htm

Size of some databases

- Human genome-3 billion DNA base pairs, actual information content is on the order of 0.05 Gbytes (about size of Word)
- Old Fermilab tape robot – $6*10^6$ Gbyte – mostly colliding beam, Monte Carlo
- Sloan Telescope at Fermilab – 1000 Gbytes
- 10^6 Gbytes of material printed every year
- Typical education through graduate school subsumed in 1-10 Gbytes
- Lifetime of images stored on DVD might be 1000 Gbytes
- Knowledge base in a human brain-0.25 to 2.5 Gbyte range (10^{11} neurons). $6*10^9$ people gives 1.5 to $15*10^9$ Gbytes to profile everyone on earth

Old Fermilab tape robot

Computing and the future

Computing speed

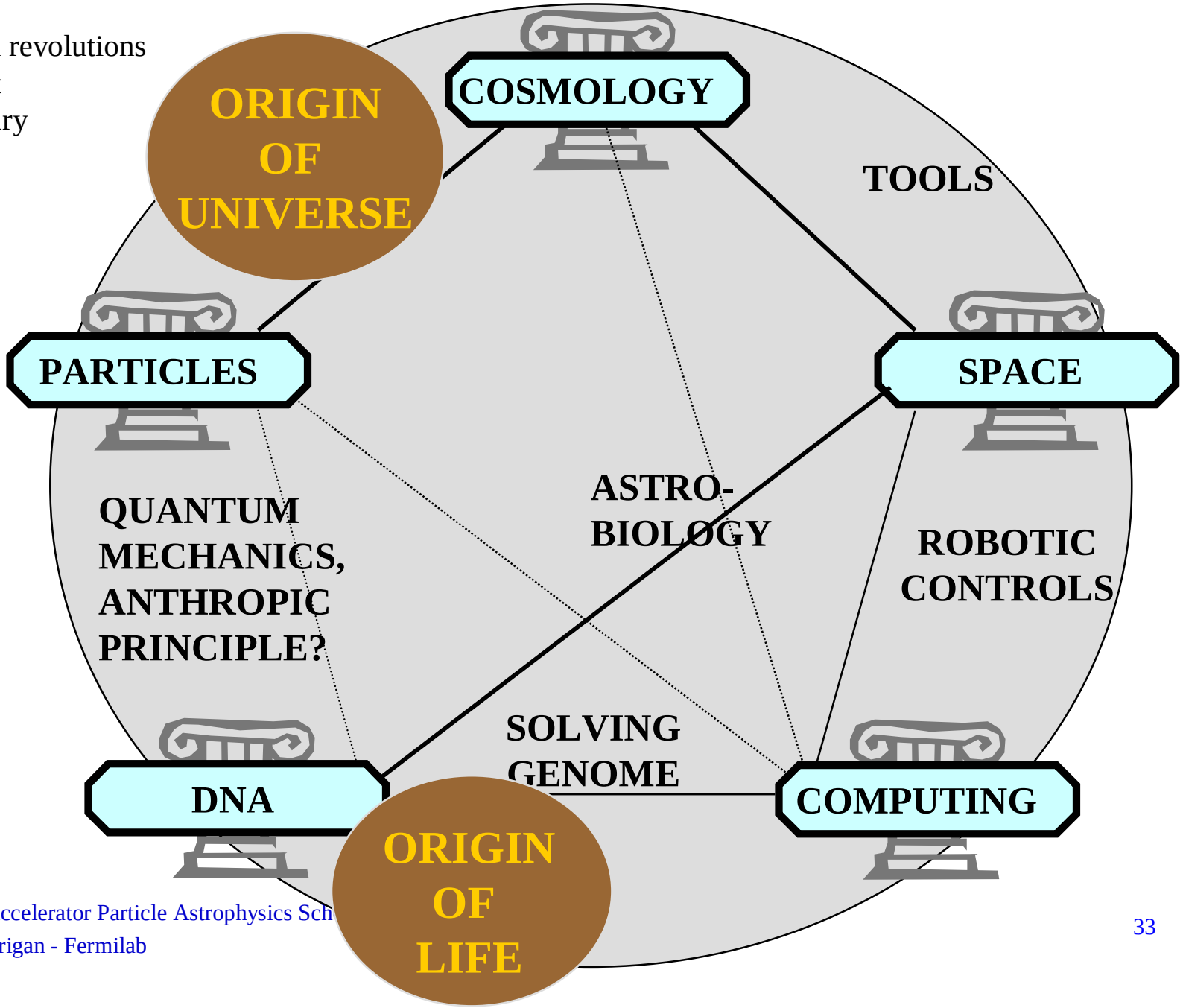
Speed of human brain - $200*10^3$ Giga computations/s (Kurzweil) or
10^5 times this computer.
Kurzweil calls the crossover a singularity
(maybe better is "phase change")
Cross over point is 2020 to 2030 at present rate of progress
QCD - 1000 Giga Flops – getting in range

Quantum computing

Problems and challenges

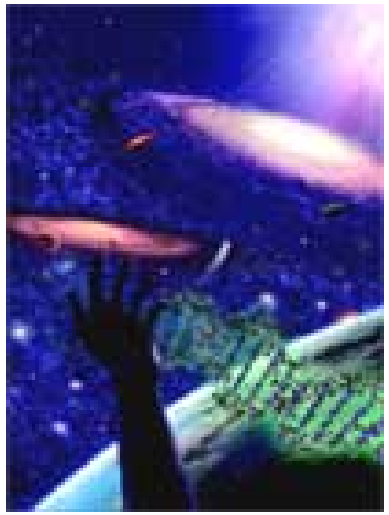
- viruses
- the approach of the Kurzweil "singularity" (or phase change)
- qualifying internet and World Wide Web
- qualifying programs
- and …**theories of computing, knowledge, mind**

Technical revolutions of the last half century



The bottom line

NASA
Origins
Program



- Particle physics and cosmology linked - explains much of the universe
- Biology has become a mathematical science
- Scientific experiments have moved into space
- Computers and computer science are reaching human capabilities
- We may find extraterrestrial life

Questions?