EINSTEIN and STRING THEORY

- Einstein: 1879 – 1955
- String Theory: 1968 – present

Certainly, Einstein did not invent string theory!
• 1905 : Brownian motion and final proof of the existence of atoms
  1905 : Explanation of the photo-electric effect (Nobel Prize in 1923)
  1905 : Special relativity and $E = mc^2$

• 1915 : General Relativity — a new theory of gravity based on geometry
  1919 : GR prediction of bending of light by stars confirmed experimentally
EUCLID — GAUSS — RIEMANN — EINSTEIN

• EUCLID: Flat, planar and fixed geometry

• GAUSS: Is 3-dimensional physical space flat or curved?

• RIEMANN: The geometry of a space can change

• EINSTEIN: The geometry of space-time is determined by its mass/energy & the curvature of space-time bends the trajectories of moving bodies.
• The happiest thought of my life (Einstein 1907)
  “An observer in free fall does not feel the force of gravity”

• Principle of relativity “The laws of physics are the same for all observers”

• Principle of General Relativity $+$ Riemannian geometry
  $=$ quantitative theory of gravity

• Successful predictions of large-scale effects, e.g.
  (1) bending of light by stars and gravitational lensing
  (2) radio echo delay and perihelion of Mercury orbit around the sun
  (3) existence of black holes
  (4) cosmological models
• Small-scale effects (e.g. atoms) are subject to quantum behavior

**THE STANDARD MODEL**

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\begin{align*}
\text{electro} - \text{magnetic force} \\
\text{weak force (radioactivity)} \\
\text{strong force (stability of nuclei)}
\end{align*}
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provides an incredibly successful theory of point-like elementary particles

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**BUT**, Einstein’s Gravity appears inconsistent with Quantum Theory

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Physicists love a good contradiction: A revolutionary idea is needed!
• View elementary particles as strings instead of as point-like particles

• Strings sense the geometry of space-time

• Strings are consistent with quantum theory ONLY WHEN
  — Einstein’s equations of gravity hold !!
  — the dimension of space-time is 10
Strings interact via the unique smooth geometry of joining and splitting.

The interactions of Point-particles are NOT unique, and NOT smooth.

This unique string interaction automatically contains:
- Einstein’s gravity!
- the interactions of the Standard Model.
SUPERSTRING THEORY

(1) A consistent quantum theory of gravity
(2) The other 3 forces appear to fit in as well

⇒ The best candidate for a unified theory à la Einstein

BUT — Einstein’s relativity was built on the principle of relativity
— String theory is NOT YET built on a fundamental principle
• The typical size of a string is expected to be $10^{-33}\ cm$, or $10^{16}$ times smaller than the smallest structures observed (experimentally hopeless)

• Space-time has 10 dimensions, of which 6 must be very small but probably much larger than the size of a string (experimentally perhaps not hopeless)

• The Large hadron Collider at CERN (LHC) will turn on in 2008 and start looking for signatures of such extra dimensions