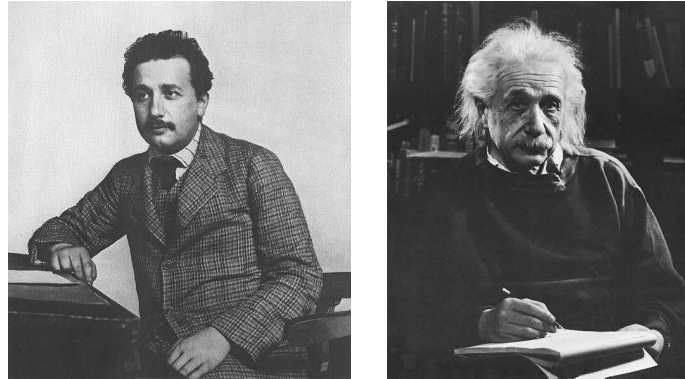


EINSTEIN and STRING THEORY

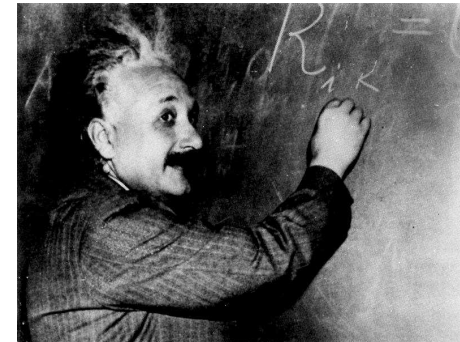
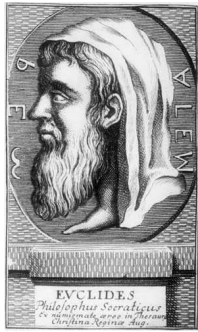
- Einstein : 1879 – 1955
- String Theory : 1968 – present
- Certainly, Einstein did not invent string theory !

EINSTEIN



- 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.

GENERAL RELATIVITY

- *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

THE CLASH !

- Small-scale effects (e.g. atoms) are subject to **quantum behavior**

THE STANDARD MODEL {
 electro – magnetic force
 weak force (radio – activity)
 strong force (stability of nuclei)

provides an incredibly successful theory of point-like elementary particles

BUT, Einstein's Gravity appears inconsistent with Quantum Theory

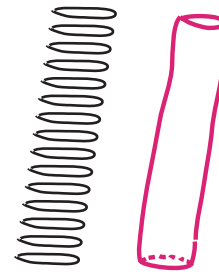
Physicists love a good contradiction : A revolutionary idea is needed !

STRINGS

- View elementary particles as strings instead of as point-like particles



Free Point Particles



Free Closed Strings

- 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

STRING INTERACTIONS



Interacting Point Particles



Interacting Closed Strings

- Strings interact via the **unique** smooth geometry of joining and splitting
- The interactions of Point-particles are NOT unique, and NOT smooth

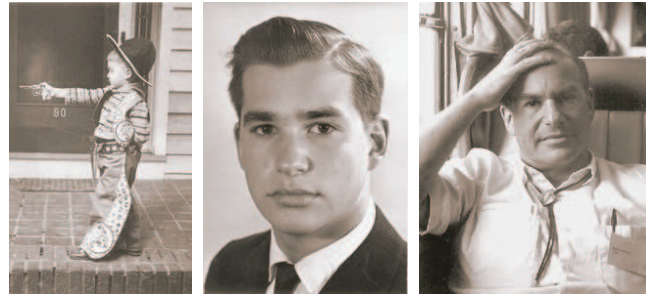
⇒ **This unique string interaction automatically contains**

- **Einstein's gravity !**
- **the interactions of the Standard Model**

SUPERSTRING THEORY



Michael Green



John Schwarz

- (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**

EXPERIMENTS ??

- 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