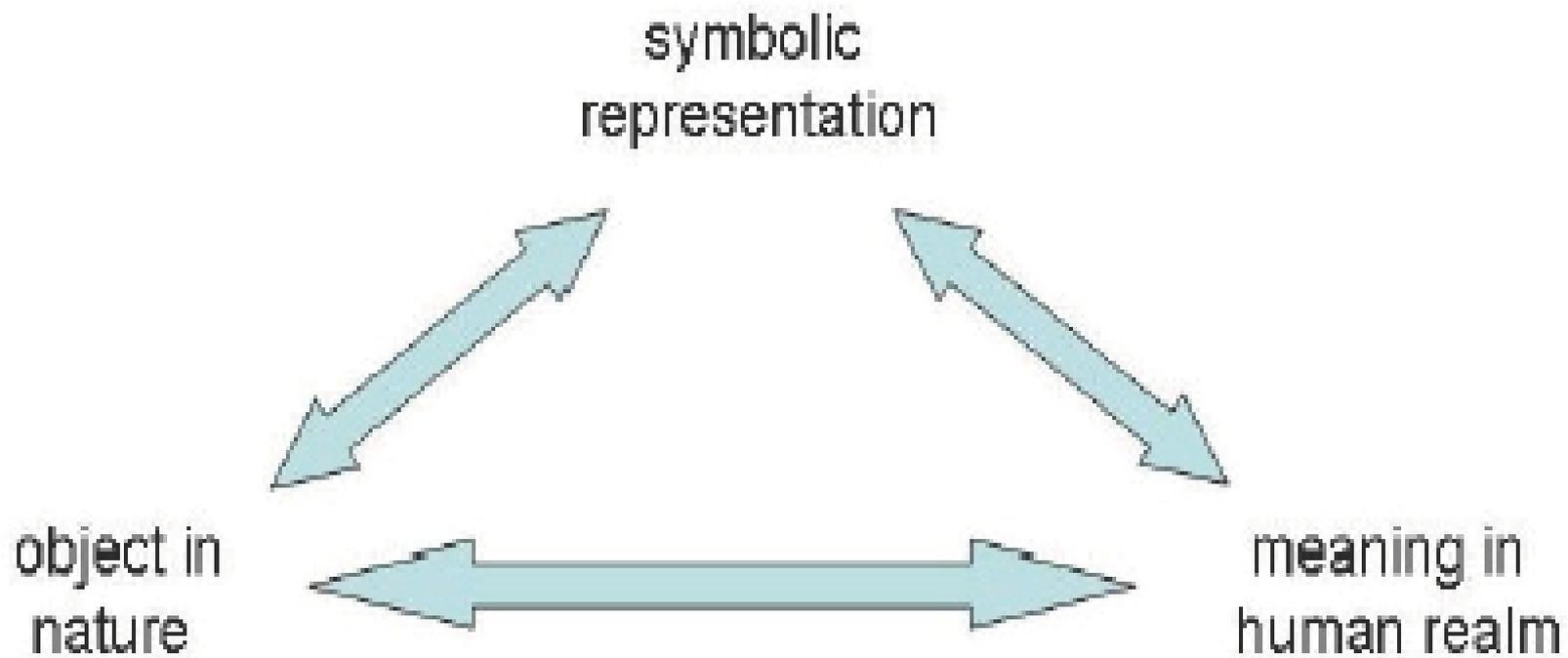
The background of the slide is a light gray color with a pattern of faint, overlapping scientific sketches and diagrams. These sketches include various geometric shapes like circles, lines, and spirals, resembling technical drawings or early scientific illustrations. The text is centered and presented in a bold, black, sans-serif font.

THE ROLE OF IMAGES IN SCIENCE: SOME THOUGHTS

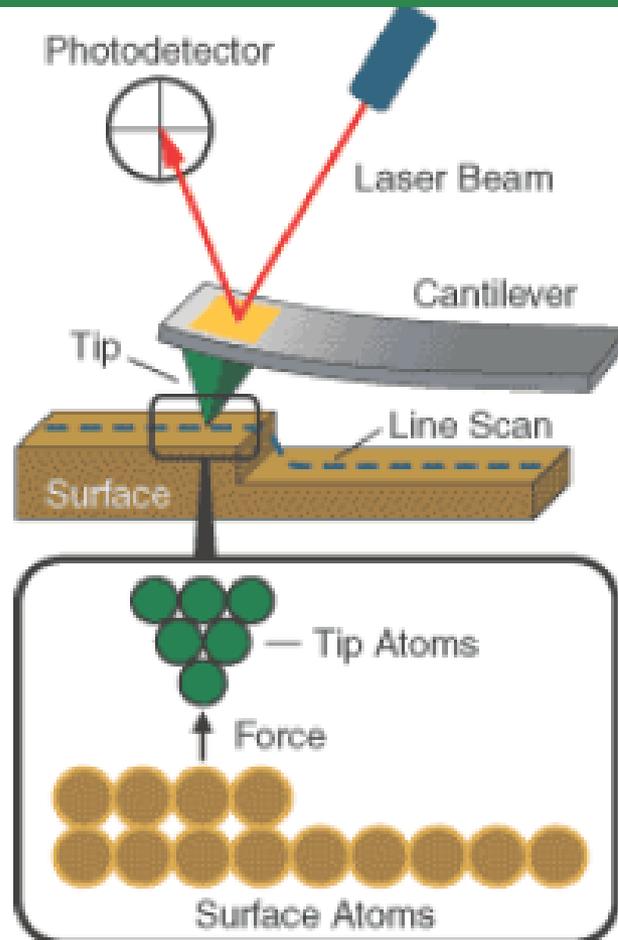
**Jatila van der Veen, Ph.D.
Department of Physics, UCSB**

**Discussion for MAT254
Fall Quarter, 2013**



According to Bruno Latour (2002), scientific images are about *“building reference chains through a cascade of transformations from matter to form.”*

Schematic of an Atomic Force Microscope

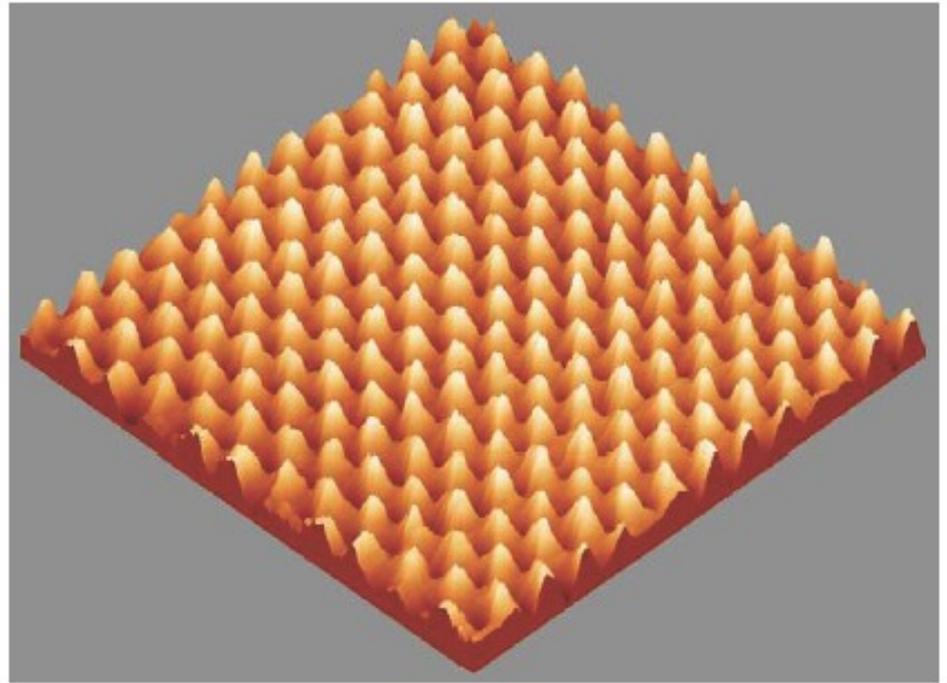


http://www.molec.com/what_is_afm.html

Images taken with an Atomic Force Microscope

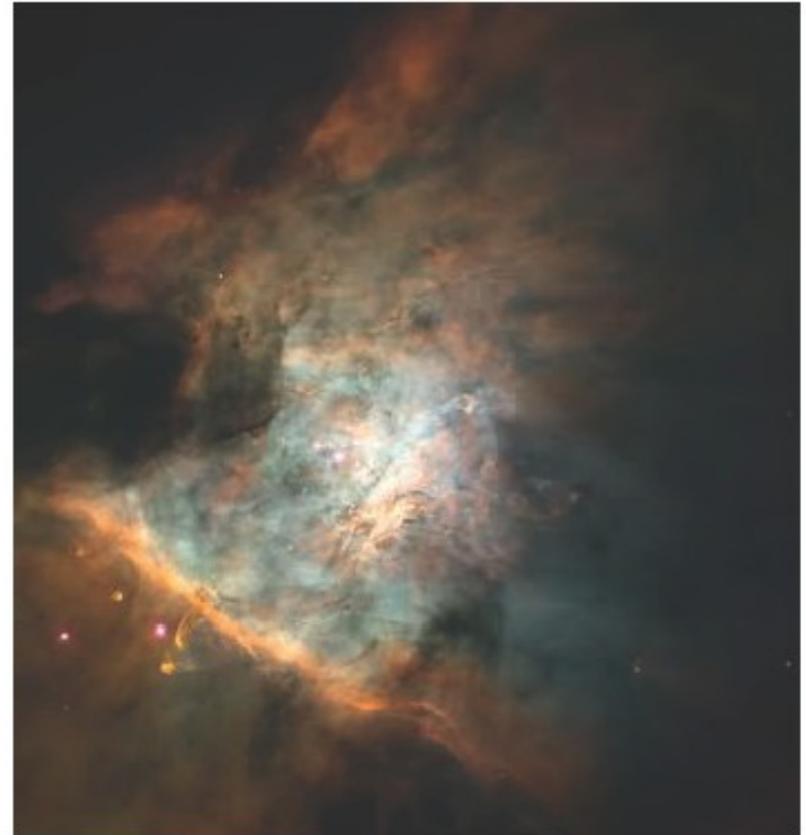
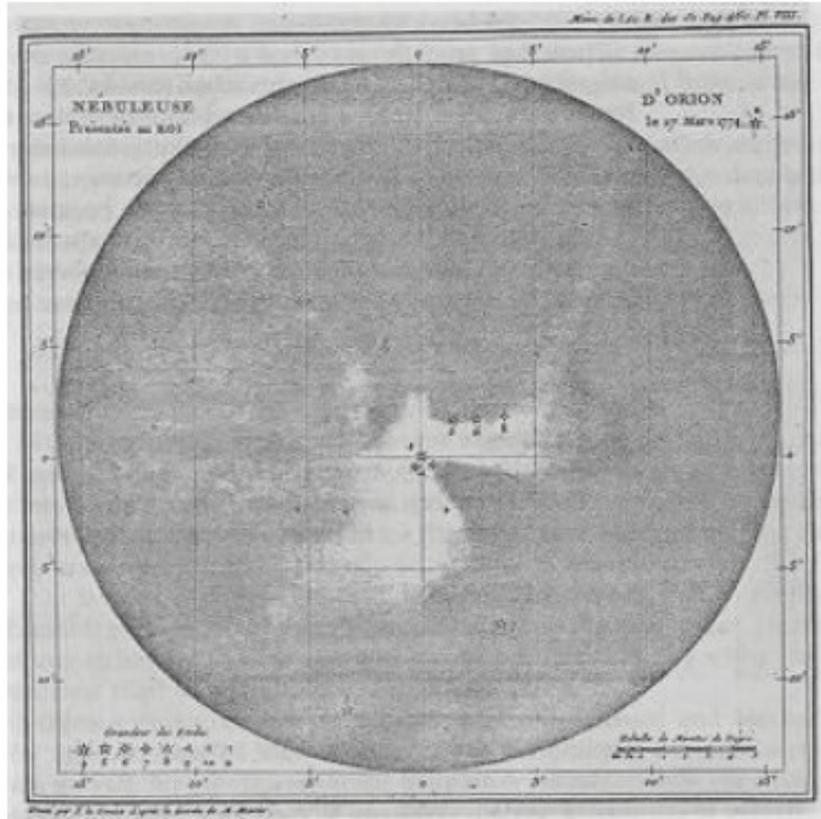


Image of Carbon-60 “molecules” taken with the scanning tunneling microscope in the Hansma Lab, Physics Department, UCSB, ~1994.
Courtesy, Professor Paul Hansma



Atoms of Highly Oriented Pyrolytic Graphite (HOPG).
<http://www.physics.purdue.edu/nanophys/stm.html>
URL visited May, 2006

More sophisticated images =
farther removed from direct sensory experience



**Sketch of Orion Nebula, M42,
Charles Messier in 1769**

**Composite image of Orion Nebula,
M42, Hubble Space Telescope in
1995**



Aesthetics: The branch of philosophy dealing with the nature of beauty, art, and taste, and with the creation and appreciation of beauty. (Wikipedia)

**Symmetry: Sameness within change
Expressed as regularity of form,
repetition in space and time,
recognizability, interchangeability of
parts, constant relationship of parts to
whole.**



initial conditions

Which allow us to distinguish among the various...

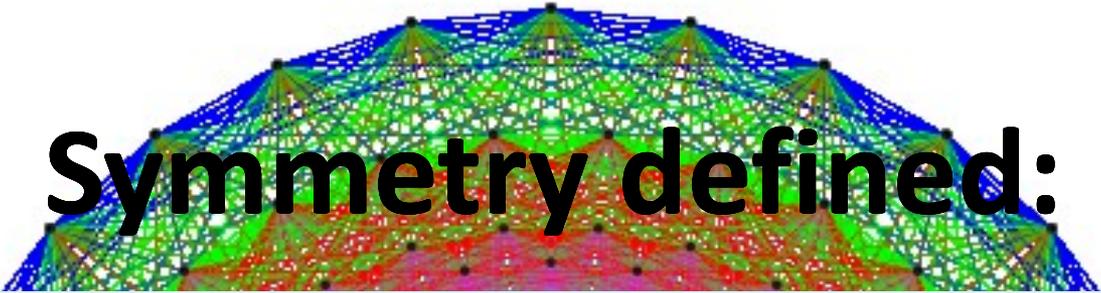
**Phenomena in the
Universe**

which GIVE STRUCTURE to the ...

Laws of Physics

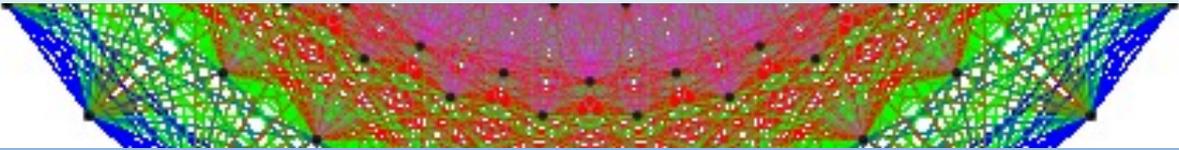
GIVE STRUCTURE to the...

**Symmetry
Principles**

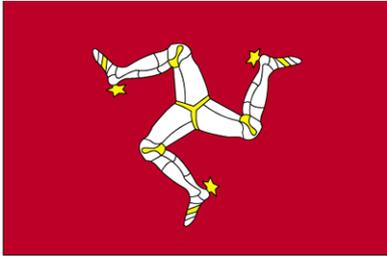


Symmetry defined:

Any system is said to possess symmetry
if
you make a change in the system
and after the change, the system looks
the same as it did
before.



*All known laws of physics can be traced to
continuous symmetries in Nature.*



rotational symmetry

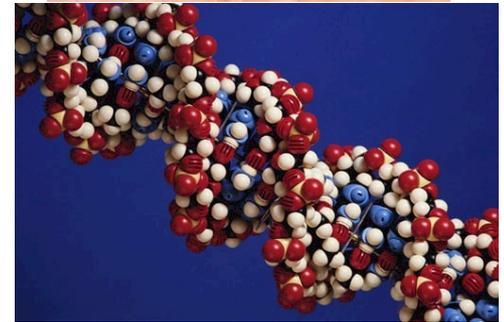
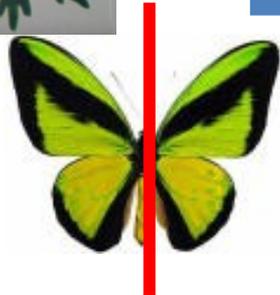
screw symmetry = translation + rotation



translational symmetry

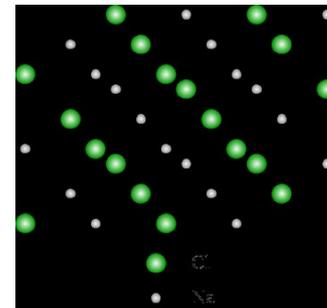


reflection symmetry

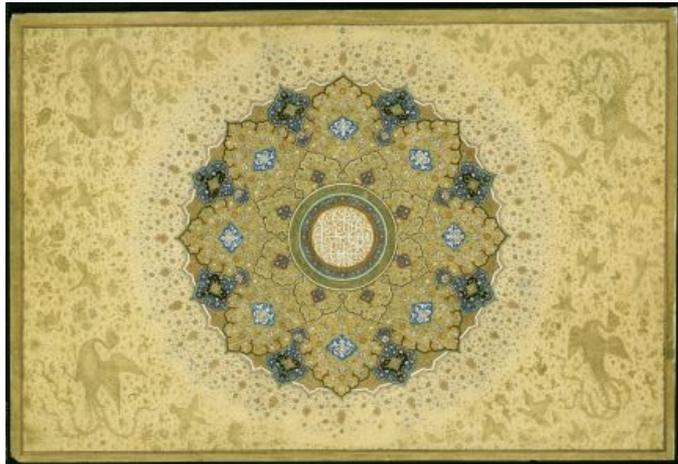


glide symmetry = translation + reflection

There are 3 basic types of observed symmetries in Nature, and 2 composites.



Symmetry operations – rotations, translations, reflections and permutations – have fascinated humans, and are apparent in many artistic expressions in dance, music, and visual arts.



Symmetry is apparent in crystal shapes in Nature, which reflect internal ordering of atomic structure...

These are the “Platonic solids” :

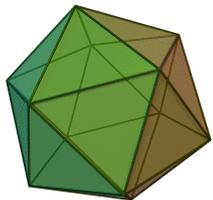
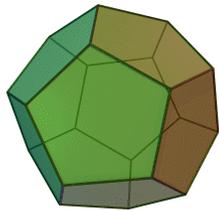
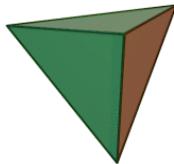
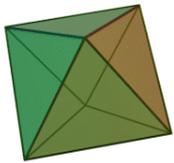
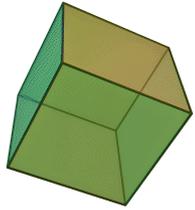
4 triangles = tetrahedron

6 squares = hexahedron (cube)

8 triangles = octahedron

12 pentagons = dodecahedron

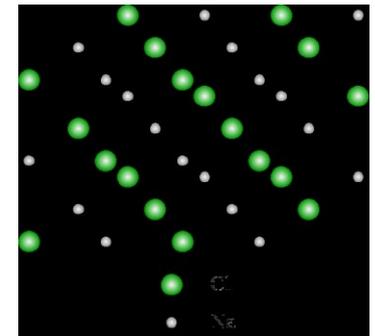
20 triangles = icosahedron



halite (hexahedron)



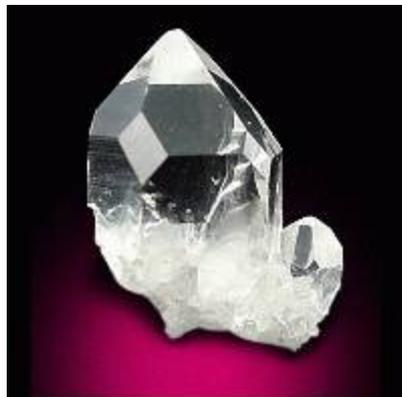
fluorite (octahedron)



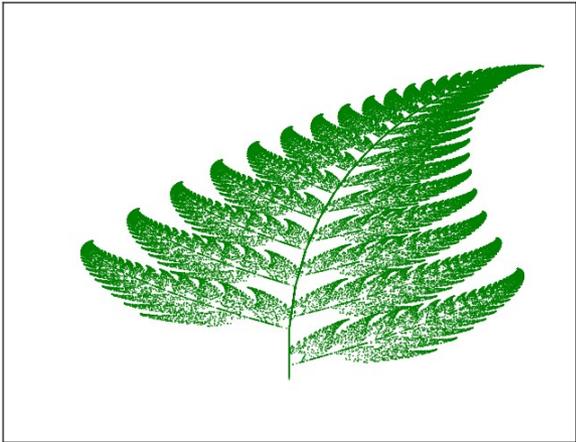
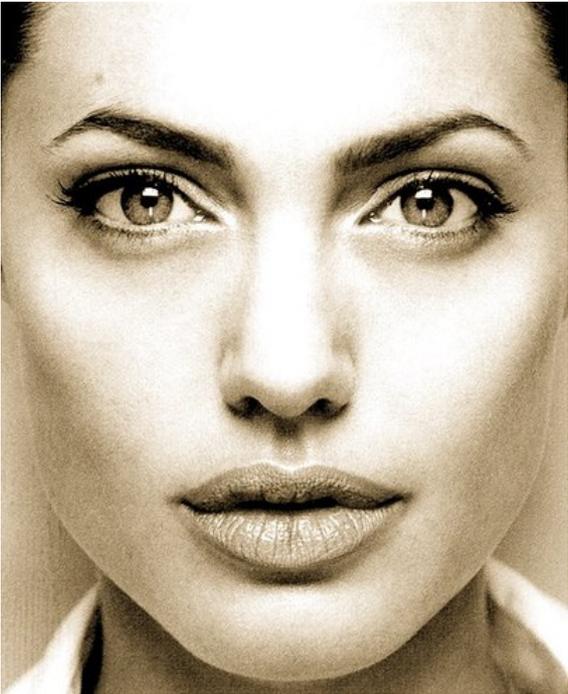
garnet (dodecahedron)



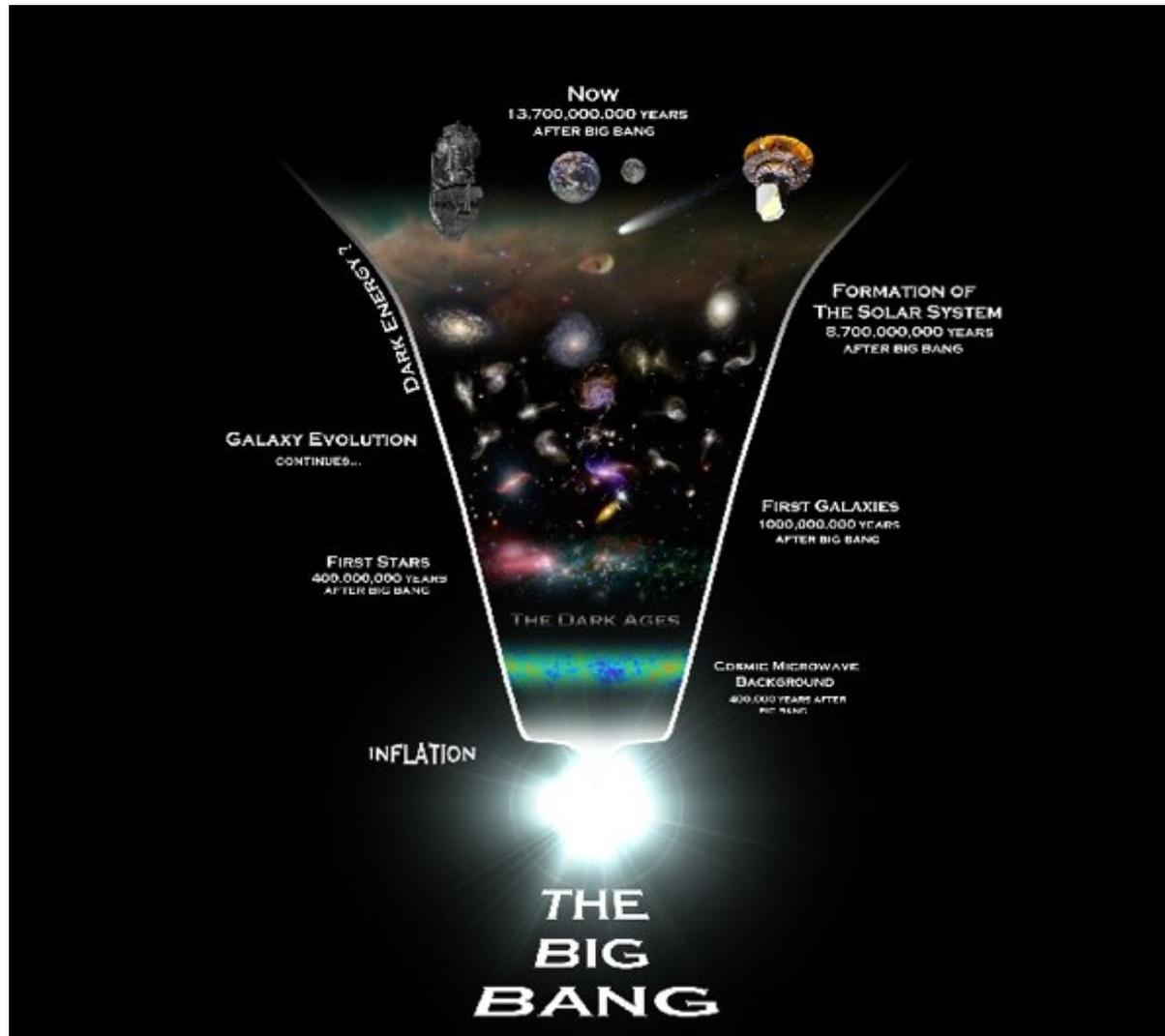
quartz (combinations)



... and in biological systems, evolution seems to favor certain kinds of symmetries.



Broken symmetry seems to have been an important aspect of the origin of our universe...



- **Patterns in nature reveal hidden laws that govern regularity in form, function, and development, which can be described mathematically.**
- **Understanding the mathematical relationships allows us to discover underlying SYMMETRIES that dictate the form of the Conservation Laws of Physics.**
- **Each time we come up against observations which don't fit our current theoretical framework, the discovery of a new symmetry has led to a PARADIGM shift in the way we understand the phenomenological universe.**

PARADIGM:

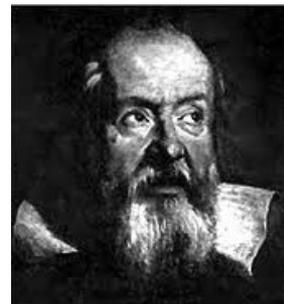
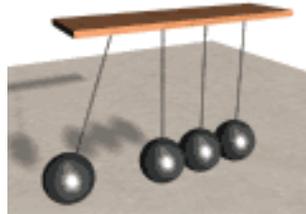
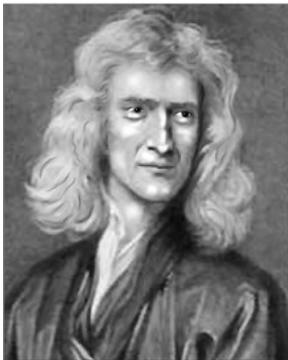
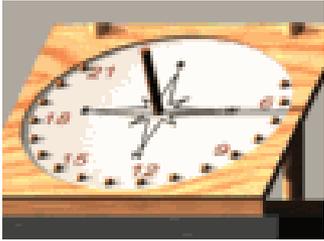
- * the framework through which an individual interprets the world and interacts with it;
- * the world view within which a scientific discipline is conceived, and within which observations of Nature are interpreted .

Each new paradigm shift is/was motivated by observations of phenomena that violated the accepted symmetries.

*The goal of fundamental physics:
To find the quantity which remains the same under rotations, translations, and Lorentz boosts.*

Classical Physics ~ Galilean Symmetry

- Time is the same for all observers
- Space is static and unchanging
- Newton's Laws govern all interactions in Nature
- The observer is separate from the observed



Modern Physics :

Special & General Relativity

~ Poincare Symmetry

Speed of light = constant for all observers

$$\Delta s^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

$$E^2 = \gamma^2 c^2 - m_0 c^2)^2$$

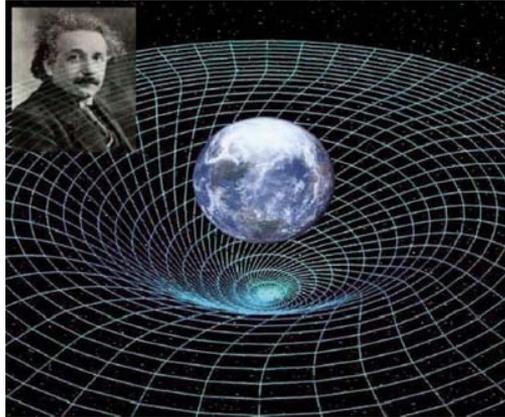
Quantum Mechanics:

~ Gauge Symmetry

$$\Psi = \psi_1 \cos\theta + \psi_2 i \sin\theta = A e^{i\theta}$$

$$\Psi = A e^{iS/\hbar}$$

Wave-particle duality



THE EINSTEIN FIELD EQUATION

$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$



“Post-modern” Physics: Quantum Field Theories and Cosmology

Elementary Particles

Quarks	u up	c charm	t top	γ photon
	d down	s strange	b bottom	
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z Z boson
	e electron	μ muon	τ tau	W W boson
	I	II	III	Force Carriers

Three Families of Matter

Particle Physics and Beyond

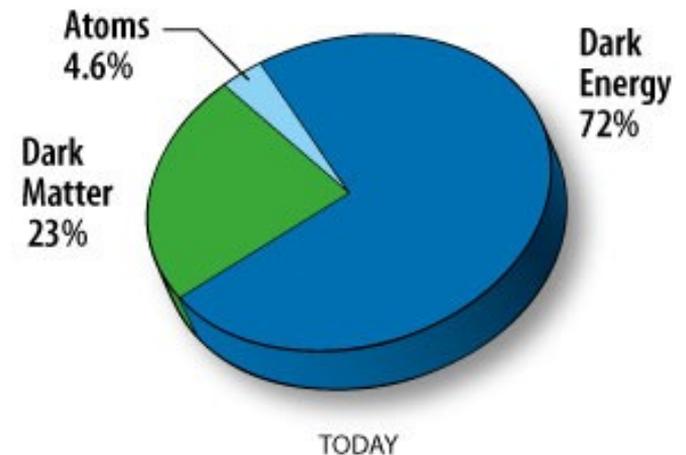
Standard Model of Particles and Interactions

Searching for new theoretical frameworks to resolve broken symmetries

Cosmology

Standard Cosmological Model: Inflationary Big Bang ;
The Universe is dominated by dark matter and dark energy. *~95% of all matter and energy in the universe is in some DARK form that we don't yet understand.*

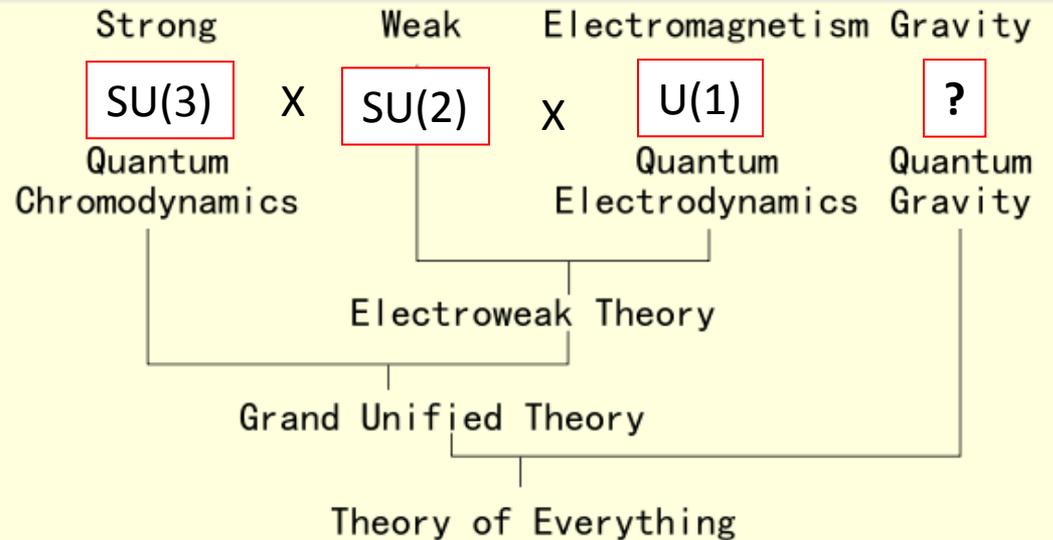
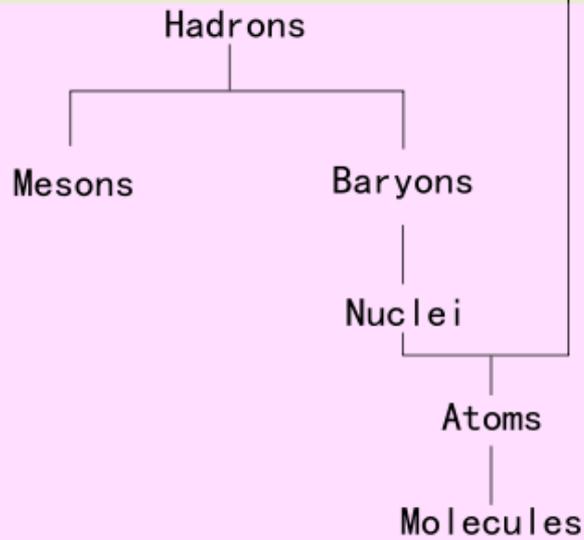
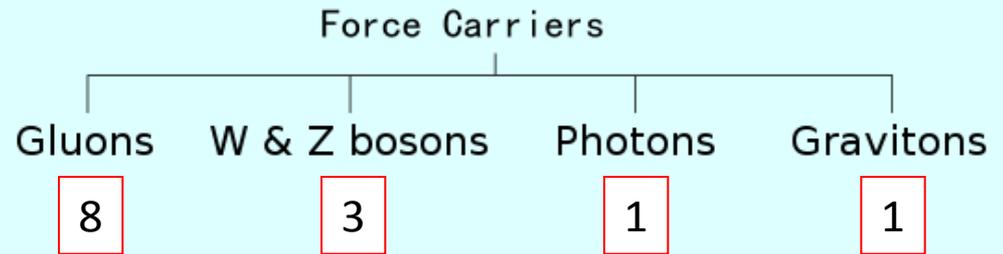
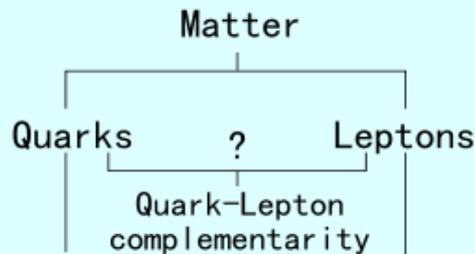
The Universe is currently accelerating in its expansion, but we don't know why.



Contemporary Physics:

Looking for new Internal Symmetries – rotations in “internal spaces”

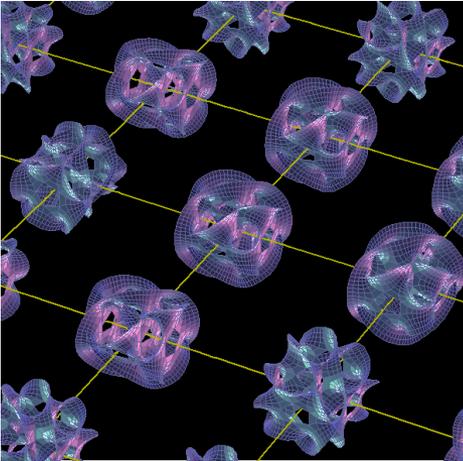
Elementary Particles



Composite Particles

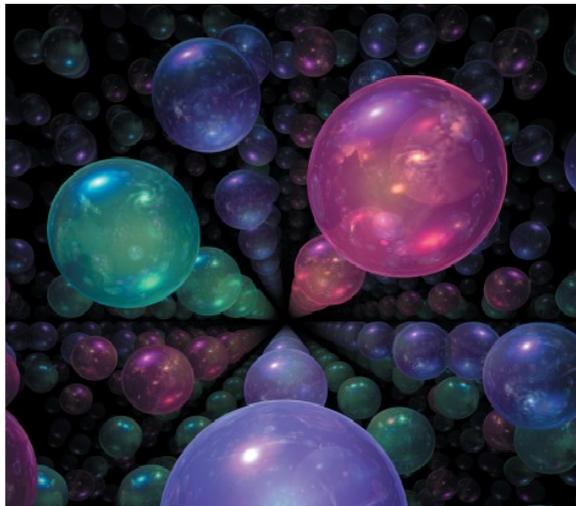
Forces

New theoretical frameworks in Contemporary Physics: Super Symmetry? String Theory? Other???



String Theory:

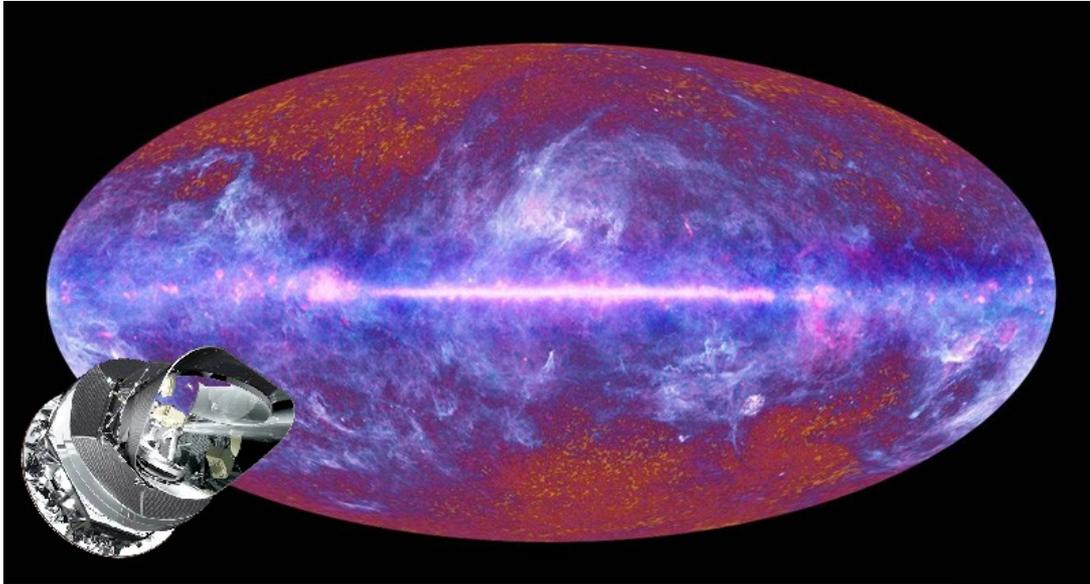
The universe is 11 dimensional – maybe even 26 dimensional. These extra dimensions co-exist with our ‘normal’ 3 spatial dimensions + time, but are curled up so we can’t see them.



Multiverse:

There may be infinite parallel or branching universes but we cannot send information across to them; they are expected to exist as a result of mathematical theory;

Searching for Answers in the Data:



**Planck Satellite:
Measuring the
fluctuations in the Cosmic
Microwave Background,
the oldest light we can
observe**

**Particle Accelerators:
Colliding particles at ultra-high
energies that approach conditions in
the very early universe**

