Physics Notes

Physics is the most pretentious of the sciences,

for it purports to address all of physical reality.

The primary classifications of modern physics are

i) The small
ii) The large
iii) The complex

The small

Two key developments of the 1960s:

i) quark theory

All particles can be grouped into two classes:

Heavy, strongly interacting particles (hadrons) which feel the strong nuclear force

Leptons (electron, neutrino) which interact through weak force

Quark theory says that hadrons are comprised of quarks. Note that the force between individual quarks in a hadron is basically very simple-- but the interactions between hadrons is complex because it reflects systems of quarks interacting.

Only quarks and leptons are elementary.

ii) Salam-Weinberg theory showing that EM and weak forces were part of a more embracing electro-weak force

In quark theory, “gluons” play the role of the “messenger” particles that get exchanged between quarks, like photons get exchanged between charged particles. Analog to QED is quantum chromodynamics.

The 1970s have seen a series of “grand unified theories” or GUTS attempting to unify strong and electroweak force.

Also efforts to construct “theories of everything” (TOEs). Most promising theory to date involves superstrings.

The Large

New astrophysics is very exciting.

At the largest length scales, physics becomes cosmology, the study of the overall structure and evolution of the universe.

Cosmology is becoming the testing ground for high energy particle physics, and marries the very small with the very large at early times.

The application of quantum field theiry to the universe as a whole has spawned the subject of “quantum cosmology”, the weirdest branch of the New Physics.

Hawking argues that quantum cosmologyhas removed the need to improse special initial conditions on the universe; indeed, there is no “origin” to the universe at all, in spite of the face that time is finite in the past!

The Complex

Only recently that complex systems have received systematic study as a physical science--in part because of computers which allow simulation.

Perhaps the most spectacular example of spontaneous appearance of ordered behavior in a macroscopic system is superfluidity and superconductivity.

Quantum optics is another example of self-organization--i.e., the laser.

The unusual propensity for matter and energy to self-organize into coherent structures and patterns is only very recently becoming appreciated by physicists. Partly this is because of the longstanding emphasis that physicist have given to linear system. Self-organization and the related subject of chaos are essentially nonlinear in nature.

What is quite unexpected intuitively is that every very simple systems, perhaps with only one or two degrees of freedom, can behave in a fashion which is in some sense infinitely complex--so-called “deterministic chaos”.

The idea that a system can be both deterministic yet unpredictable is still rather a novelty. The reason can be traced to the system-s extreme sensitivity to intial conditions.

Ford argues that chaos provides the “missing link” between the laws of physics, so familiar to the scientist,a nd the laws of chance, equally familiar to the gambler.