Having completed our survey of the standard model and some surrounding territory, it's appropriate to reflect on the big picture. What does it teach us? What does it mean?

To keep the discussion organized, and to keep it from getting too heavy, I've adopted the "List of Ten" format. So here are 10 big lessons from the standard model, organized into four categories: epistemology, natural philosophy, emergent simplicity, and unfinished business.

Epistemology

1. *Reductionism Works*

The premise of reductionism is that you can understand how things work by analyzing them into constituent parts with simple properties and interactions, and then build back up. As a strategy for understanding the physical world, its been brilliantly successful! As we've seen, matter as we know it, in all its richness, can be analyzed into vast numbers of identical copies of a few ingredients, whose properties and interactions we can describe quite fully and very accurately. Moreover the required interactions are local in space and time, so we can build up our understanding, if we're sufficiently clever, from small to large scales. It appears that we have the adequate foundation, in fundamental physical law, for all applications of physics in chemistry, biology, materials science, engineering in general, astrophysics, and major aspects of cosmology.

2. *The Surface Appearance of the Physical World is Quite Different from its Deep Structure*

In general, the world-picture of quantum theory, with its elements of indeterminacy and discreteness, appears quite different from the everyday world of experience. There is still considerable work to be done, I think, to show convincingly how observed macroscopic "classical" behavior follows from the underlying quantum equations, even at the level of mundane low-energy physics. High-energy particle physics takes things further. We find that the familiar, effective building-blocks of low-energy physics, *i.e.* protons, neutrons, electrons, and photons, are themselves complicated objects, when expressed in terms of more truly fundamental entities. For protons and neutrons this is notorious: They are complex bound states of quarks, antiquarks and gluons, which are the primary entities. Quarks, antiquarks and gluons obey simple mathematical equations; protons a nd neutrons don't. But protons and neutrons are how the equations get embodied, empirically. Less dramatic, but also profound, is that electrons are put together from left- and right-handed massless quanta with disparate fundamental properties – specifically, different weak isospin and hypercharge. And photons are mixtures of weak B_3 and hypercharge C mesons. It is those objects, not the emergent photon, whose properties are ideally simple.

Natural Philosophy

3. *Relativity (Poincare Symmetry), Quantum Mechanics, and Local (Gauge) Symmetry Rule*

For upon assuming these principles we can construct, deductively, the standard model, which describes empirical reality.

4. *The Distinction of "Matter" and "Light" is Superficial*

For the building-blocks of matter are essentially massless, and they can be created and destroyed – properties that, traditionally, are regarded as characteristic for light.

5. *"Empty Space" is a Substance*

It is filled with pervasive condensates, and also exhibits spontaneous activity. Both the condensates, and the fluctuating activity ("virtual particles", vacuum polarization) radically alter the qualitative properties of particles moving through "empty space".

6. *Nature Loves Transformations*

So that the superficial count of dozens of degrees of freedom, is reduced to a much smaller number of independent ur-substances.

Emergent Simplicity

7. *The Behavior of Matter at HIgh Energy Simplifies, and Reveals Its Deep Structure*

We can calculate much of the behavior at high-energy accelerators. Jets of observed hadrons follow calculated patterns set by underlying quarks and gluons.

8. *The Early Universe is Open to Rational Reconstruction*

For the big bang gives us conditions of extreme high energy density, where the equations for matter dramatically simplify (asymptotic freedom).

Unfinished Business

9. *We've Got Vexing Family Problems*

The replication of fermion families is unexplained, and brings in many new phenomenological parameters, whose measured values have not been illuminated by profound theoretical ideas.

A (The?) bright spot here is the tiny overall phase of the quark mass matrix, which can be explained by axion physics.

10. *Unification Looks Good, and Suggests Low-Energy Supersymmetry*

The observed group-theoretical quantum numbers of $SU(3) \times SU(2) \times U(1)$ multiplets fit beautifully into an encompassing $SU(5)$ or, even better, $SO(10)$. Unification dynamics works quantitatively, and explains the relative strength of the different gauge interactions, if we include the extra vacuum polarization associated with low-energy supersymmetry. Gravity fits too, at least roughly, although a meaningfully detailed theory of its possible unification remains elusive.

∞. *Bonus Item: Dark Matter*

It seems clear that the standard model, as currently understood, does not account for the astronomical dark matter. On the other hand, that dark matter does look like its composed of some kind of relic gas of particles, surviving from the early big bang. Axions are a good candidate to be that particle, as are possible stable particles arising in low-energy supersymmetry.