Many (all) the questions have been answered during the Q&A period. Nevertheless, we ask that you provide written answers below so students can come back to read them again. Thanks!

1. Imagine we discover a leptoquark (in light of some flavour physics anomalies). How would this be accommodated in the unification theories?

The first thing to do is identify the leptoquark properties (whether it is a Lorentz vector or a Lorentz scalar, and its charges with respect to the SM). Grand unified theories generally have both scalar and vector leptoquarks with specific SM charges, dependent on the GUT symmetry group and the symmetry breaking chain to the SM. The vector leptoquarks are quite directly traced to the structure of the GUT group, while the scalars are connected to the (more model-dependent) Higgs sector.

2. Is SUSY ruled out by the recent CMS measurement of the decay rate of Bs->mu+mu- spot on the SM prediction?

SUSY models have a proliferation of parameters related to the soft supersymmetry breaking sector, which is associated with the masses and mixings of the SUSY partners. While specific models of the supersymmetry breaking parameters can be constrained/ruled out based on this measurement, it is not possible (for better or worse) to rule out the framework of TeV-scale SUSY.

3. (Page 7) What do the balls/circles and lines represent?

These are Dynkin diagrams, which are used to characterize Lie algebras. They encode what are known as the simple roots (the roots are related to properties of what is known as the Cartan subalgebra of the group). In the figure on slide 7, the two connected circles in the SM diagram denote SU(3); the single circle is SU(2). There are four connected circles in the SU(5) case. Note than in groups other than SU(N) we have angles and directions in the Dynkin diagram.

4. (Page 10) How do we get unified gauge coupling? How does it do the prediction?

The unified gauge coupling arises from the fact that as an input, we have a single gauge group with a single coupling at high energies. Once the GUT symmetry is broken, the coupling constants of the subgroups evolve independently.

5. (Page 10) We usually pay more attention to the unification of the gauge couplings (i.e. supersymmetry theories), while the unification of the Yukawa couplings are ignored. What is the reason? Should the perfect GUT theories predict the unification for both gauge and Yukawa couplings?

Yukawa unification is studied in detail in GUT theories; the main reason why it is not as famous as gauge coupling unification is that it doesn't work well (or really at all) for the lighter generations. There are many ways this can be "fixed" in the Yukawa sector, but most require inputs beyond just GUT structures. The problem of the origin of the fermion masses and mixings in the SM is an extremely difficult problem which transcends just GUT theories.

6. (Page 15) Is there any deep implication or ideas about quarks and antiquarks in the same representation?

At the level of a GUT, all entries of a multiplet are equivalent and related by symmetry transformations. It is only after the symmetry breaking to the SM subgroup that the notion of "quarks" and "antiquarks" is meaningful.

7. (Page 12) Can you say some more about the misleading situation on weak neutral currents that it may not exist? Non-observation put a limit on cross section. How did we get to a much stronger statement that it did not exist?

My apologies for the confusion and indeed you are right: what I should have said is that it was not clear from the experimental data that it existed due to the limit on the cross section. At the time the theoretical situation was not clear, so models both with and without the weak neutral current were considered.

8. (Page 20) In SU(5) theory, since SU(3)c group is unbroken in the second step of SSB, why do we need 5-plet Higgs scalar to proceed the SSB in this step?

The 5-plet is needed to incorporate the SM Higgs that breaks the electroweak symmetry.

9. (Page 24) Phenomenology for the diquarks?

Diquarks contribute to proton decay (both leptoquark and diquark interactions are needed). They can also contribute to other baryon-number violating processes.

10. Are M_X and M_Y of the same order?

Yes, with the adjoint Higgs breaking in SU(5), they are the same order.

11. (Page 8) If we knew neutrinos mix earlier, what might be the closest alternative/extension to SU(5) to accommodate ?

Since PS and SO(10) evolved around the same time, these are natural candidates. Note right-handed neutrinos are easily accommodated in SU(5) through a fermion singlet representation.

12. (Page 25) What is the doublet triplet problem?

The doublet-triplet problem is that in the 5, the doublet is the SM Higgs and should stay light, while the triplet must be heavy to avoid rapid proton decay.