Esteemed Graduates, Parents, Colleagues and Friends, Welcome to this Joyous Event!

I want to start by thanking you for this implausible privilege. Every day I remind myself how truly lucky I am to be a member of this quite astonishing community.

Before all else, I want to offer my most heartfelt and earnest congratulations to the students we are here to celebrate. I have myself experienced this day two times, once while pursuing my own PhD and once as the proud parent of an outstanding biology graduate student at the University of Washington. These two beautiful documents that I hold in my hands were labors of love, the culmination of the same kind of journey you have just completed. Both of them are a testament to our mission into the unknown, the power of perseverance and the deep joy to be found in the study of nature. But I must say, the second one was so much better.

I want to keep my remarks brief, while doing everything in my power to make them meaningful to both you and me. My aspiration is to speak as authentically and sincerely as possible, fully cognizant that what I say is entirely subjective. So here I go: First, with every fiber of my being I believe in inspiration. Each year, I ask our new physics graduate students, how many of them are here because of the efforts of a single teacher. The surprising answer is that it is well over 50%. In my case, on a magical Saturday in April of 1977 I had such a moment when I went to a friend's house for a 7pm living room lecture on the so-

called anchor point of history, the story of how great discoveries about how Eratosthenes measured the radius of the earth, the rise of analytic geometry as Descartes figured out how to unite the great concepts of space and magnitude, how the last naked eye astronomer Tycho Brahe measured the positions of Mars, all culminating in the great insights of Newton which changed science forever. My key realization that night was that scientists ask hard questions that are driven by their own curiosity and through ingenuity, perseverance, creativity, new technologies and patience, find answers to those questions. If you had asked me that April morning long ago what I thought of science, I would have told you it was another belief system imposed by adults to try and manipulate me into some performative act. And yet, it is no exaggeration to say that the next morning I told my parents: "I am going to dedicate my life to science" and that is the reason that nearly half a century later that I am standing before you today and that same inspiration fuels my passion now.

We are here today to celebrate the magnificent achievements of our graduates. Every fall I teach an intensive bootcamp for all of the incoming students in the life sciences. I always make the remark that this labor of love we call a PhD thesis for many of us takes up a large chunk of our 20s. There is something glorious in this kind of purpose, in having a craft that is worthy of the best we have within us. I admire marathoners – people like the great Max Perutz who labored on the structure of the

single protein hemoglobin during 20 years, Edward Gibbon who over a similar two decades of dedication wrote this amazing tome, “The Decline and Fall of the Roman Empire,” I hold here in my hands, or Andrew Wiles laboring in complete secrecy in his attic for the better part of a decade while he engaged with the mystery of Fermat’s last theorem. What each of you has in common with these great thinkers was a dangerous leap of faith into the unknown and the dedication to stay with a project for years on end – the antithesis of the superficial, 140 character discourse that masquerades as knowledge and wisdom now.

I have never been a fan of the traditional school paradigm where we labor away learning about the known, constantly engaged in performance with teachers and parents watching over our shoulders. Graduate school celebrates a much more important kind of learning, learning about the unknown. As one of the inventors of the laser Arthur Schawlow once said, “to do research, you don’t need to know everything, you just need to know something that is unknown.” One of the most powerful lessons of our time in graduate school is to learn how to learn about the unknown. I know there is some confusion, perhaps especially with you parents about what graduate school actually is. I have heard stories of parents saying to their kids: “When are you going to be done with school.” The problem is that I think that is quite a misrepresentation. It is not that they are graduate STUDENTS that we should focus on. That is a misnomer. They are the engines of science and engineering.

These young people are the ones that actually do the hard work of waking up each morning and discovering and inventing.

Yesterday, I had the enormous pleasure of spending all day 14 miles off the California coast on a research vessel with brilliant young scientists from Caltech and JPL. I was privy to some of the most amazing technology that aims not only to explore the depth of our own oceans, but to make miniature devices such as this for exploring moons and planets elsewhere in our solar system. One after another I saw this collection of young people, one of whom I met nearly 15 years ago when he was a dreamy eyed freshman, engaged in exactly the kind of things that all of you have also been doing in recent years. Congratulations.

I can't resist letting one of these students speak for himself:

I came to Caltech as many do - seven AP's, straight A's, perfect SAT's, loaded with extracurriculars and a heartfelt acceptance essay, blah blah blah.

I like and concur with the blah, blah, blah part – we are not here to perform with APs, perfect SATs and straight As, we are here to change the world by creating knowledge and inventing unimaginable new technologies. Perfect SAT scores and straight As is not necessarily the road to those achievements.

I'm now designing the systems for a rover that will be pushed into an icy lake at the northern tip of Alaska and left entirely alone for three months as the days

fade into total wintery darkness. — But I've never done that before. Has anyone?

These moments—when you attempt something so foreign—feel risky. But if the Caltech community taught me anything, it's that when something feels scary in this particular way, it's worth running straight toward it.

No greatness is achieved without a willingness to fail, and the will to try again despite that failure.

I've learned that the surest way to fail is not to try at all. And the surest way not to try is to let doubt overwhelm your innate curiosity. That childlike wonder to reach out and hold the world in your hands.

I'm not sure I can improve upon what Russ had to say, but let me add my own spin. It has been said that "specificity is the soul of credibility." In that spirit, let me speak about what it is that I have tried to take away from my own graduate school experience, what I hope you will take away from yours and what I hoped that my two very bright kids would take out into the world from their unfinished educational journeys.

- First, an unapologetic embrace of the sense of wonder. There is an apocryphal tale that Einstein said we have two choices, take everything as a miracle or nothing. I am unequivocally in the former category.
- Next, an idea I might call the humility null hypothesis – the central posture we assume when we work to learn about the unknown is "I don't know." This spirit animates our work in the lab, at our desks, on our computers. And honestly, I have very little doubt that the world would be a

better place if we all simply tried to use these words a little more often.

- Mistrust of all mobs, group think and collective wisdom. Science is not about authority figures. Ever. You are the judge in your own court. In graduate school, hopefully you realized that it is not the reviewers of your papers that are your worst critics, but rather that person that greets you in the mirror each morning.
- Live with a deep appreciation of the achievements of others. Everywhere you look there are amazing accomplishments of young people like you. More colloquially, be a lover, not a hater.

I feel very strongly about all of these aspirations and to my mind, they all share one common feature. Do not fall into the trap of emotional and intellectual laziness. Especially the part about being a lover and not a hater. Being a hater is lazy.

In closing, I have a few final thoughts.

Last year I led a Caltech alumni trip for people just like you to take in the pleasures of Italy while considering Galileo, Fermi, Avogadro, Lagrange and others. I was again deeply moved in the city of Florence in the halls where is found Michelangelo's masterpiece, the David. The problem is that every time I go there, despite the perfection of David at the end of the hallway, I am always gripped by the Hall of Prisoners, the room full of Michelangelo's unfinished statues. That is you. That is us. Each of us has this incredible gift of an unfinished sculpture –

maybe there are cracks, maybe the colors of the rock are imperfect, but it is there for our story to be written. What I hope so much for each and every one of you, students and parents alike, is that you will leave our campus today, chisel and hammer in hand, to boldly go out and to build your masterpiece.

The great Edith Hamilton wrote a number of books about ancient Greece. As a 16 year old, I read her book The Greek Way and was struck with her assessment of the Greek definition of happiness. There she said "the exercise of vital powers along lines of excellence in a life affording them scope." It is my great hope that as Caltech recedes as a memory, that the things you learned here will serve you in the exercise of your clearly vital powers.

Congratulations to you and your families, and to us for the privilege and pleasure of having you here! The great physicist John Wheeler once said "the real reason universities have students is to teach the professors." Thanks so much for teaching us!