

WHAT DOES NATURE WANT?

Eric Cornell – What does Nature want? It's a very important question because Nature almost always gets what Nature wants, so we shouldn't try to understand what Nature wants and the easiest way to find the answer is to ask her! I'll do an experiment, I'm an experimental scientist, I reach into my pocket, I take twenty-five marbles, twenty-five small glass balls, and I throw them into the air, I cover my eyes and I wait a little while, I wait for Nature to tell me what it is she wants. I open my eyes and I see the answer! I see that Nature is kind of like me. She's lazy. What do I mean by lazy? Why should I stand up if I can sit in a chair? Why should I sit on a chair if I can lie on the floor? I'm lazy... And I see that Nature is the same way, the marbles are all on the floor, they are not all on the ceiling, they are not all on the wall. Nature wants to be lazy. The other thing that I see about Nature is that she's also like me: she's sloppy. You look around my office, my office is disorganized, just piles of paper, it's not beautiful, and I look on the floor and the balls have rolled all over the place, they are not in a perfect row of five times five times five times five, twenty-five little marbles all on a box, no, they are spread everywhere. That is sloppy. Nature, like me, is sloppy and lazy, but! I turns out, Nature cannot do both of these at the same time! There is, maybe I would call it The Great Dialectic of the natural world, is the struggle between laziness and sloppiness. You can't have both. If Nature wanted these marbles to be maximally sloppy, some should be on the ceiling, some should be on the floor, some should be on the wall, some half-way in-between, floating in the air, but that never happens, because that's not a very lazy thing to do. She can't be maximally lazy and maximally sloppy at the same time...

How does Nature make this choice? It turns out, we can understand much of what happens in the Universe by understanding Nature trying to find the perfect compromise between laziness and sloppiness. And that compromise comes from making as small as possible this number I'll call F which is the figure of compromise... And, we want to be small, I mean instead of calling it laziness, I'm gonna call it "oppiness", the opposite of unlazy... She wants to have as little unlaziness as possible. So, this figure of compromise, I'm just gonna say it's the same, it's gonna be equal to unlaziness, and then I want the sloppiness to be big! So, I'll put a minus sign, unlaziness minus sloppiness. And you say, okay, I want to make this as small as possible, but it turns out on some days, Nature is more concerned about sloppiness, and on other days she's more concerned about unlaziness! So we'll have an exchange rate, which I wanna call T , for the trade-off factor... And this thing, trying to minimize this, is exactly what Nature does, and in physics, of course, we don't really call it unlaziness and sloppiness, we call it energy, we call it entropy, and this trade-off variable we call it temperature... So much of physics, so much of biology

and chemistry we can understand, is Nature trying to satisfy at the same time her two vices, her two bad habits, her sloppiness and her laziness at the same time, she can't do both, it has to do with the temperature...

One final example: if you had a box, and inside the box you had some water, maybe there'd be some water, some liquid water, some ice and some water vapor. If it's on a day where the temperature is very, very small, T is very small, then T multiplies the entropy, the sloppiness, that's not very important, Nature concentrates on minimizing the energy. Having the water molecules all sticking together, it's ice, when the temperature is low, ice minimizes this number called the free energy. If the temperature is very, very high, the energy is not very important, the entropy, the sloppiness, is important. And indeed, if we make the temperature very high, we see vapor inside the air, not water, not liquid, not ice... So, it's interesting to ask the question: what is it that Nature wants? And it's a little disturbing to find that she, like me, has some bad habits and these are very important... I have been describing Nature as a person with bad habits, I don't actually believe that. I believe that Nature is just the order of the Universe as it presents itself to us, and how it unfolds, and we try to understand that, mmm, because we are people, when we try to understand things we think about people, maybe I think about Nature as a person, but not really...

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