On the laws of nature

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Plenty of people have asked the question "*why does matter behave the same everywhere in the Universe?*" It sounds a very deep question. I remember as a student when first being introduced to Schrödinger's equation, which seemed to me pretty complicated, asking "*how do simple things like electrons know to obey this?*" The answer I received clearly wasn't a life-changing insight because I've forgotten what it was, if indeed my tutor ever came up with one. That question is a bit deeper than my initial one. If you think about it, if electrons behaved differently in different parts of the Universe that would be something that really needed an explanation. That would be a much more complicated situation. The fact that electrons always behave the same way is the simplest of all possible scenarios. They behave the same way because they are intrinsically identical; identical and simple objects, embedded in space-time that itself is the same in different parts of the Universe.

The fact that simplicity underlies the apparent complexity of nature we encounter on a daily basis has been a driving force behind the evolution of physics. Physicists have looked for underlying laws of nature that seem to work everywhere. On the whole, they haven't been disappointed in their search. Does it require explanation that the same laws work everywhere or would it require more explanation if they didn't? In my view what we have discovered is that the simplest of all possible circumstances prevails in nature. The same laws and properties apply everywhere. I'm not sure that does need an explanation. It would be a departure from that situation that would require explanation.

Explanations and understanding need to start somewhere and my stating point is that at a fundamental level the building blocks of nature are identical in all parts of the Universe and the space-time in which they are observed is identical. The initial question "*why does matter behave the same everywhere in the Universe?*" is not a deep, meaningful question because there is no more fundamental observable concept by which it can be 'explained'. It is this starting point, supported by experiment, that makes the Universe intelligible. Given the complexity of nature that we observe it is surprising that it should be so but it answers Einstein's comment "*The most incomprehensible thing about our universe is that it can be comprehended*". The universe can be comprehended because underlying it is the simplest of all possible organisations. That's my first point.

Asking how electrons 'know' to obey Schrödinger's equation is not quite so naïve as it may sound, though of course 'knowledge' such as we have in our heads is a highly complex phenomenon and not a concept relevant to an electron on its own. To see part of the issue involved, think back to the Ptolemaic description of planetary motion. This was a synthesis in the 2nd century AD of attempts over several hundred years to predict the location of planets in the sky. The model described by Ptolemy had the Earth at the centre of the Universe and the planets performing motions described by a complex geometrical system of equants, deferents and epicycles. How did the planets know to follow such a complex system of motion? Or, in the language of mediaeval Europe, 'Why did God make planetary motion so complex?'. Well, of course He didn't. And, besides, the predicted positions of planets were sometimes wrong by a degree or so, which mightn't sound much on a desktop protractor but is a huge amount in the sky.

Copernicus's alternative heliocentric description appeared to be simpler and Copernicus himself said it needed only 34 epicycles to make a better model of planetary positions, though it may have actually taken some more. Still, why did God need as many as this for only 7 'planets' (including the Sun and Moon)? He didn't. Kepler demonstrated that with the introduction of ellipses planetary motion could be described by only 3 laws. Actually one needs many more than 3 parameters for even a single planet to predict its position in the sky because an ellipse needs 2 parameters to define its shape and several more to define its orientation in space and how that orientation changes over time. Nonetheless, most of the parameters refer to accidents of a planet's location and these are different from the 3 'laws'. Why 3 laws? Finally, Newton's single law of gravity replaced Kepler's 3 laws, which were shown by Newton himself to be a consequence of motion under the inverse square law of gravitational attraction. So the question 'why did God make planetary motion so complex?' as applied to the Ptolemaic model was a good one and strongly hinted that the model was not a fundamental explanation of what was going on. Later science reduced the explanation to one law (supplemented by 'universal' laws of motion) and, indeed, a law that wasn't special to planets either. The search for an explanation also led to a clear distinction between the underlying law(s) and the special circumstances needed to describe a given situation.

Laws, then, are usually mathematical descriptions of how nature works. Schrödinger's equation for quantum systems is another example. In this view the law is not an attribute of the object it describes but it is a behavioural description. Fundamental laws are the end point of scientific enquiry. To ask 'why' a law is true may either lead to the realisation that the law is a consequence of something more fundamental (as in the examples above and in the next paragraph) or is a question that has no answer in science.

As Newton's laws of motion and gravity show, a law of nature can explain what is happening in a wide variety of circumstances. All laws, though, aren't equal. For example, Kepler's laws of planetary motion could be deduced from Newton's laws and the extent to which they are approximations also deduced. Newton's law of gravity can itself be deduced from Einstein's theory of General Relativity, and the extent to which Newton's law, too, is an approximation answered. So some laws are more fundamental than others. Are the most fundamental laws connected? This is the question that the '*theory of everything*' is attempting to answer. It's the motivation for developing string theory and its derivatives. If string theory had been successful in this respect, you would already know about it. Looking for a connection between the laws is a logical next step for physics, which is why many physicists in recent decades have been attracted to the problem. Whether there is a connection between fundamental laws now seen as independent is a 'cutting edge' question.

People have been hoping that fundamental laws of physics will come out of string theory and its more recent variants, laws like the rules of quantum mechanics and the equations of general relativity. Moreover, can the *theory of everything* predict both the existence of the particles we find in nature and their properties, essentially the fundamental physical constants? There are good reasons for continuing with the development of string theory and related ideas like 'brane' theory but although they haven't yet delivered the unification that motivated their pioneers, their apparent failure has had one important spin-off. Far from giving us the observed fundamental constants of nature, string theory suggests that the 'landscape' of possible combinations of fundamental constants is huge. That there may be as many as 10^{500} (in round numbers!) possible combinations of fundamental constants and variant physical possibilities. So why should the universe we find ourselves in have the particular combination that it does?

This question has spawned two ideas that keep cropping up. One is the *multiverse*, namely the concept that there do indeed exit other universes, that may or may not be connected in some way with our universe, in which the physical constants are different. The second is the *anthropic principle,* which has several variants but states that the constants in the universe have the values they do because these values support the life we find in the universe (and other values would not). The multiverse concept has been dismissed by some cosmologists because it seems to be unprovable by any scientific tests. They argue that it is therefore outside science and becomes a matter of philosophy or, worse, a matter of faith to be believed or not without the possibility of any supporting evidence. Moreover, the multiverse concept has no predictive power and is therefore not a proper scientific concept. It is also no real explanation of the detail of our existence to propose that there also exists an almost uncountable number of other universes that we can never experience. Physics may have a lay reputation for explaining the known in terms of the unknown but this surely takes the biscuit? On the evidence so far presented, I more or less agree with this assessment.

The anthropic principle has also been slated for not having predictive power. Of course we live in a universe in which life is possible, for we couldn't live in one in which life is impossible. It may be true that in the landscape of possible physical constants there are many others in which a different kind of life is possible (we don't know) and it may be true that the kind of life we know about can only exist within a very narrow range physical constants (we have a better idea that this is so) but that still doesn't tells us why the physical constants have the values they do. It tells us only that their values are consistent with us being around and our environment being what it is. Is it a valid question to ask why the Universe is like it is?

To pick one of many relevant references, Paul Davies has spelt out in a very readable paperback [*The Goldilocks Enigma,* Penguin Books, London, 2006] various contending answers to his question 'Why is the Universe just right for life?'. My own view is that this is an emotive version of the more general question – 'Why is the Universe like it is?' Why pick on life? Why does the Universe have the stars it has, creating the elements they create? Why solids, liquids and gases? And so on. Life is an emergent property of atoms, albeit a property of staggering complexity, so effectively the question is 'Why is the universe the way it is with the properties it has?'.

What physics has been very successful at doing is deducing unifying ideas from which much of the huge diversity of the physical world can be explained, at least in principle if not always in detail. As time has passed over the last four centuries, the unifying ideas have become more powerful and hence more fundamental. For example, a material's properties are understood in terms of the configuration of its atoms in space and the forces that hold its atoms together; atoms are understood in terms of the energy levels and electronic configuration of their nuclei and electrons, as deduced from the laws of quantum mechanics and relativity; nuclear stability is understood in terms of the interaction of the constituent nucleons which in turn are described in terms of quarks, gluons and the strong and weak nuclear forces. However, following any line eventually leads to the end of the line and what happens at the end of any line? You can tie a knot in the line; you can fold it over and tie it off; you can splice the separate threads back into each other but none of these techniques hide the fact that the end is the end. As with real lines, so with lines of argument. Questions such as why the universe is the way it is can't be answered within the laws that describe the Universe, which is what physics is about. This is why theologians (our distant ancestors in reality) invented Gods who were completely outside nature – 'supernatural' beings who provided the motivation for why nature is like it is. However, that only moves the question up a level for one can ask with equal validity why the Gods are the way they are. Theologians tend to come back with the answer: “they just are the entities they are”. So the line of argument ends abruptly, without ‘explanation’ for the unbelieving. To make another analogy, one can keep going north kilometre after kilometre, but only for so long. There will come a time when you can no longer go north, for you are at the north pole.

Just because we think we can imagine a universe with different physical constants doesn’t mean to say that ours has been selected from a huge range of possibilities. Imagination of alternative scenarios doesn’t bestow any reality on them, though the multiverse camp would have us believe it does. My view is that asking why the universe is the way it is is asking a question that has no provable answer. It sounds a valid question but in reality it isn’t. The lack of an answer in no way takes away any meaning to life, as far as I’m concerned. Meaning to life is provided by human culture; it doesn’t come bundled with the raw stuff of nature. The string theorists may come up with a deeper understanding of particle physics and the laws of physics than we now have and it won’t be for lack of effort if they don’t. I doubt if they will answer questions such as ‘Why is mathematics the key to understanding the universe?’, which it seems to be. This is another question that can’t be answered from within the realm of mathematics and physical science. I guess my answer is that when you have the key in your hand, don’t spend much time wondering why it is the shape it is but put the damn thing in the lock, turn it and open the door to a real understanding of how the universe works.

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