Forces of Nature

We have no notion of their mechanism of action

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AI generated abstract: The author argues that while physics is useful for prediction, some fundamental theories, like particle interactions, are purely descriptive and lack a mechanistic explanation. The author uses the example of electron repulsion to illustrate how physics relies on arbitrary labels and force fields without explaining the underlying mechanisms. The author contrasts this with Darwin's theory of evolution, which provides a mechanistic explanation for a natural phenomenon

"All science is either physics or stamp collecting" is a quote attributed to the physicist Ernest Rutherford. The implication is that the other sciences simply involve the collection of data, either by direct observation of nature, or by the observation of the results of experimental challenges to nature, whereas physics provides fundamental mechanisms and explanations for the interactions of matter. In this piece, I aim to dispute such an assertion, even though I am sure that it was a remark made off the cuff in an attempt to tease scientists from other disciplines.

Physics is certainly an exact science. It uses experiment and theory, mostly mathematical, to develop theories of the Universe. My assertion is that some of those theories, often at a very fundamental level, are purely descriptive, they do not explain. They enable prediction of events in the future because they describe the nature of events in very precise mathematical ways. This is very useful to humankind. However, the models are purely descriptive. They do not give any extra insight into the mechanism of events which happen in the Universe.

The best example I can give is the interaction between two particles, which is just about as fundamental an interaction as one

can get. Let's consider two electrons approaching each other. At some point they will no longer be approaching each other but moving apart. We describe them as repelling each other. Indeed, the motion of the two particles is predicted by mathematical equations that exquisitely give their forthcoming trajectories, such as Coulomb's law…

$$F = \frac{q_1 q_2}{r^2}$$

The repulsive force between two electrons depends on each of their charges, q_1 and q_2 and is inversely dependent on the distance between them, r, squared. The equation provides no insight as to how the particles experience this force.

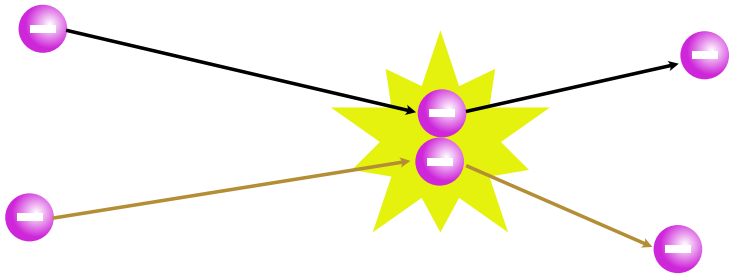
Et voilà, we can now predict what will happen next time electrons approach each other, which is quite useful, We do need to understand our own logic, here. Firstly we talk about electrons. Wikipedia defines an electron as "a subatomic particle with a negative one elementary electric charge." We know what a particle is, a fragment of matter. Subatomic means making up part of the atom. So far, so good. But what is electric charge? This is a physicist's jargon for a property that a particle can have which causes effects on other types of particle which they describe in a body of knowledge loosely described as electricity. What is a negative electric charge? This is where things get sticky and we use classification to help us describe particles and what they are doing. We assign arbitrary names to particles and their properties to help us through the complex web of interactions. Of course such names in no way help us understand the processes, just to describe them. According to the Chamber's dictionary, the name electron is derived from the word electric. The name has no

fundamental significance other than being a useful label.
Observation shows us that electrons repel each other. In order to describe this phenomenon, we assign electrons with an electric charge. Electric charge is a measure of the tendency for electrons to repel each other. A group of electrons has an accumulation of such charge. Electrons are attracted to other particles which we have given the name protons. A force of attraction occurs between electrons and protons, but forces of repulsion occur between two electrons or between two protons. This observation led to the notion that *like charges repel and unlike charges attract.* Because we observe such attractions and repulsions in experiments (which involve observing the attraction or repulsion of large scale objects with deficits or excesses of electrons, notably using a gold-leaf electroscope) we have assigned opposite charges to electrons and protons. This leads us to a necessary but arbitrary decision, how do we distinguish between these two different charges. Because we have this observation that electrons and protons are attracted to each other, we assign them with opposite charges. This assignment in no way gives any explanation as to why opposite charges attract, nor why like charges repel. We have given the electron a negative amount of charge and the proton a positive unit of charge. This is entirely an arbitrary decision. We could have labelled them the opposite way round without disturbing our theory in any way. We could have called electrons blue meanies and protons as anti-blue meanies and the logic would have been just the same.
It seems intuitively obvious that two colliding particles like electrons would move apart after the collision, in the way that snooker balls would. The observed reality, however is much more

mysterious. Two electrons approaching each other repel before they meet. This is known as action at a distance. This is common to several forces of nature. The Moon is held in orbit around the Earth without contact with the Earth. The force of gravity acts at a distance, as does the electrical force between electrons. There have been several attempts to explain the mechanism for such action at a distance, all of which are wholly unsatisfactory.
The first was to use the concept of a force field. This was the idea that charged particles have a region of influence outside themselves that cause a force to exist between themselves and other particles. There was no explanation of how this force field manifest itself, it really said that particles attracted each other in the region of this force field because they do. That is the observation. Electric fields and gravitational fields are simply a semantic way of describing the mysterious repulsion or attraction of particles or other bodies when they are close enough to one another. There is no real physical explanation of how this field manifests itself or how it operates. Einstein did draw analogy between the force field due to mass, the gravitational field, and a distorted rubber sheet. He said that matter distorts space in the same way as a mass on a rubber sheet influences the motion of objects moving on it by distorting the sheet. Like many such theories, this use of analogy is just that, an aid to think about what is going on. The question that must then be posed is how does matter distort space? What is the mechanism for this? Without such qualification, we are just replacing one unknown magical phenomenon with another (and would the rubber sheet analogy actually work in deep space, where there is no gravity to cause the particles to be drawn into the bottom of the sheet?)

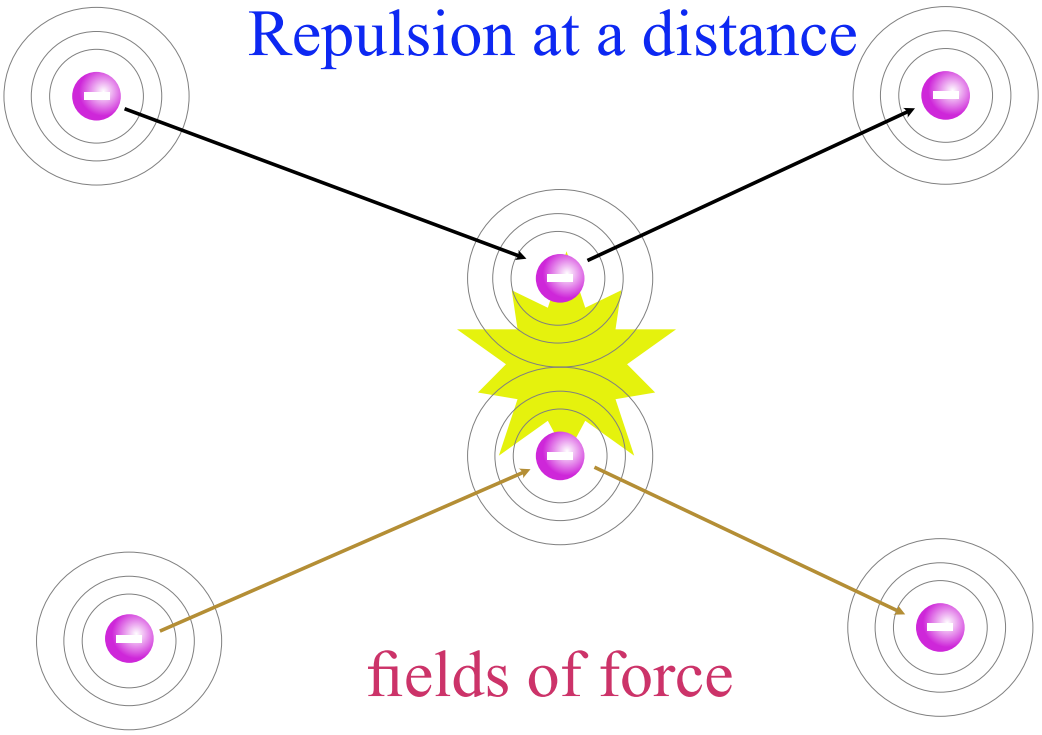
Richard Feynman attempted to address this problem of action at a distance. As two electrons approached each other, a physical particle, a photon, was exchanged between the two, causing them to repel. This has led to the preponderance of “Feynman diagrams” showing a photon emitted by one particle colliding with a neighbour, causing repulsion or attraction. A problem is solved by a simple diagram. Except that it just removes the problem of action at a distance by one step. What causes the photon to know that there is an adjacent electron? At a distance, a photon is generated by an electron and traverses space to cause a repulsion event. How does the first electron recognise the presence of the second electron in order to release the force carrying photon? Physicists then regress back to the electric force field to explain that. This takes us back to square one. It seems that, when reduced to the basic nitty gritty, the physicist’s explanation as to why electrons repel is, well, because they do.

This is not to say that scientific theory is unable to provide mechanistic explanations. In the modern interpretation of Darwin’s theory, the idea that random mutations provide variation in a population, and that the environment selects those variants most well adapted to survive in that environment seems to me to provide a complete mechanistic explanation for the process of evolution. We have a good understanding of the chemical process of mutation, step by step, and the environmental factors that cause them.The terminology is not relied on for a coherent logical explanation of the process of evolution. So all science outside physics is not simply stamp collecting, but physics itself can sometimes be purely descriptive of events.



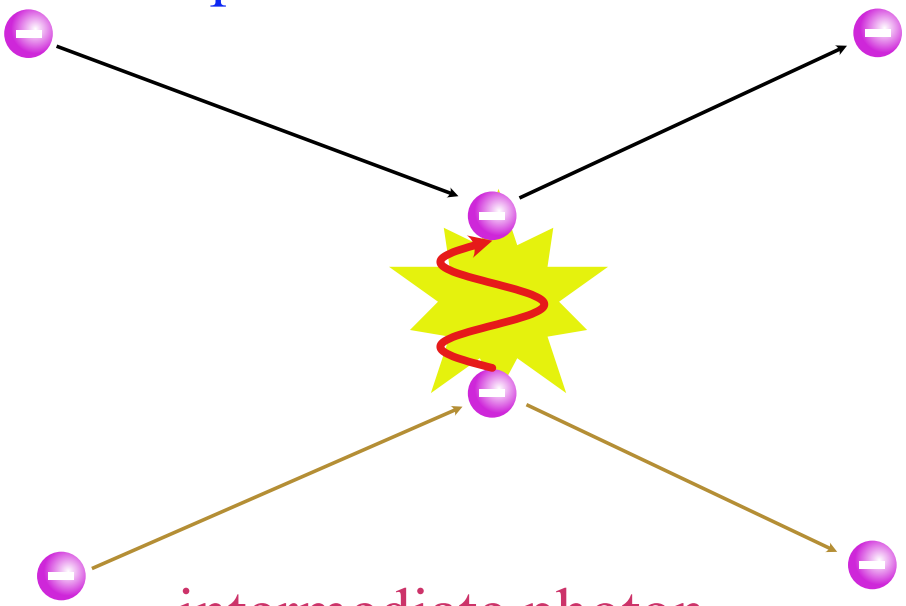
Repulsion by direct contact

Repulsion at a distance



fields of force

Repulsion at a distance



intermediate photon