Is a realist attitude justified towards the theories of modern physics?

Semantically, a realist attitude refers to commitment to literal interpretation of scientific claims about the world. Such semantic commitment contrasts with instrumentalist epistemologies of science, which interpret descriptions of the unobservable simply as instruments for the prediction of observable phenomena.

This essay argues that the realist attitude cannot be justified towards the theories of modern physics. I will first refute the two common arguments for realism, namely the '**miracle' argument** and Hacking's **'entity realism'**, and then show that **underdetermination of theories** further undermines its validity.

1. **Refuting Miracle Argument**

Many realists rely on the fact that science has been incredibly successful to argue that scientific realism is "the only explanation that doesn't make the success of science a miracle".

Successful novel predictions, often involving the unobservable, like the bending of light by the theory of general relativity or Bell experiments' confirmation of quantum entanglement and hence resolution of the EPR paradox, seem to provide an intuitive justification to scientific realism.

Argument 1

However, there are two major problems with this 'miracle argument'.

Firstly, is realism really the only plausible explanation for the success of science? Most theories that are considered successful have permitted certain degrees of manipulation or what may be regarded as ad-hoc hypotheses in order to work.

For example, the Standard Model involves a total of nineteen free parameters that have to be empirically determined in order to fit the data, from masses of fundamental particles, their coupling strength to quark mixing ratios. Meanwhile, general relativity has led to the postulate of dark energy and dark matter that cannot be experimentally detected, and thus has remained as an unfalsifiable ad-hoc hypothesis to save general relativity from being refuted.

If we take into account such manipulations crucial to most of the modern scientific theories, their successes immediately become less 'miraculous' than realists' claim.

Argument 2

The second problem is that most of the scientific theories are in fact been far from successful. The history of science is full of cases of empirically successful theories proved to be false; therefore, by induction, our current successful theories are likely to be false.

Indeed, none of the nascent theories of modern physics is without problem. The Standard Model gives wrong predictions of the atomic radius of muonic hydrogen (differing by 7 standard deviations) and the magnetic dipole moment of muon. Most famously, quantum mechanics and general relativity are not clearly compatible, which suggests that either or both are likely to be proven false.

As a result, scientific theories are clearly less successful than what the realists have claimed, nor is their (limited) success a miracle that can only be explained by realism. The miracle argument thus cannot be taken as a valid justification for the realism.

2. Refuting Entity Realism

Another motivation for realism in connection with at least some unobservables comes from experimental corroboration.

Hacking, advocate of experimental or entity realism, claims that *"we are completely convinced of the reality of electrons when we … succeed in building new kinds of device that used various well understood causal properties of electrons to interfere in other more hypothetical parts of nature."* He further summarised this view in *Representing and Intervening* as, '*if you can spray them, then they are real.*'

However, Hacking's criterion for realism is both too restrictive and too permissive.

- **Hacking's argument relies heavily on an extended example on electrons while ignoring entities that are observable yet do not lend themselves to manipulation, which are very common in modern physics.**
  - For example, while we have sufficient evidence that corroborates the existence of quarks and colour, we are still far from any sophisticated manipulation of their sub-atomic strong interactions, and the idea of colour confinement suggests that we will never be able to manipulate free quarks – they must always exist in the form of hadrons. Similarly, neither Higgs bosons and nor the gravitational waves satisfy Hacking's criterion of being 'real'.
- **On the other hand, successful instances of manipulation that satisfy Hacking's criteria perfectly may turn out to be spurious**.
  - Quasiparticles in physics provide a strong counterexample to refute Hacking's stance. In condensed matter physics, absence of electron in the energy bands are characterised as positively charged 'holes', the behaviour of which is indistinguishable from point-like particles. The properties of electrons and holes have been manipulated to create semi-conductive materials, but existence of holes as point-like particles is just an illusion.
  - Similarly, physicists often simplify complicated collective excitations of a system by modelling them as interactions with quasiparticles, like phonons for vibrational excitations or magnons for spin excitations. According to Gelfert, it is possible to manipulate such quasiparticles to create a 'quasi-particle current' that can be injected – 'sprayed' – across barriers between films of different materials and interfere with macroscopic structures.
  - If we adopt Hacking's experimental realism, we should also count these obviously fictional, empirically equivalent entities as real entities.

Therefore, it is clear that Hacking's entity realism only introduces significant confusion and incoherence over what is real and what is not, and therefore is too weak to provide convincing support to the realist attitude towards the unobservable.

3. Underdetermination of Theories

Furthermore, the fact that many empirically equivalent competing theories remain underdetermined and our inability to rationally choose between such rival theories further bolster scepticism towards realism.

- For example, while the Copenhagen Interpretation is now the most widely accepted interpretation of quantum mechanics, the many-worlds theory remains as an equally competent candidate that is so far empirically indistinguishable from the Copenhagen Interpretation.

- **While many appeal to the idea of inference to the best explanation as a solution, to infer truth of an explanation based on the fact that it is the 'best' explanation is itself problematic.** ➔Not only do explanatory considerations associated with the 'loveliness' of a theory involve significant subjectivity, there is also no rational reasons to believe that the 'loveliest' theory will lead us to the truth.

- **Moreover, experiences have proven that we are bad at thinking up all of the possible explanations.**

  - The debate between the wave and particle theories of light provides a representative example of an unconceived alternative: although the wave theory was favoured compared to the particle theory by 1850, both were replaced now by the theory of wave-particle duality.
  - In such cases, we can never infer truth from our existing theories, as the best explanation we have so far are likely to be the best of only a limited subset of an inexhaustive set of empirically adequate explanations, and there is no way to foresee whether this subset of explanations happens to contain the true one.

The implication of these difficulties is obvious: if we cannot even have a rational and decisive agreement on which theory is the closest one to truth, how can we go on to argue that the truth of a theory should be interpreted literally?

To conclude, we have shown that the realists' dream of the literal truth of scientific claims cannot be justified. **A solution to the failure of semantic realism is naturally to adopt instrumentalism and re-orientate science from revealing the ultimate 'truth' of nature towards the aim of empirical adequacy.** This so-called 'shut up and calculate' ethos may disappoint the most idealistic realists, but it has inarguably led to tremendous developments in modern physics, in fields like quantum mechanics to particle physics. These developments have convinced many modern physicists that, as long as a well corroborated theory is capable of giving accurate empirical predictions, they have good reasons to have faith in it based on its empirical virtues without probing further to question its literal 'truth'.