9th Jul 2007

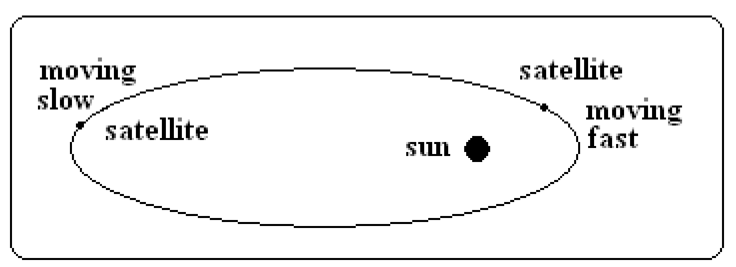
Chlorophyll does quantum computing

Nature proves to be the ultimate efficiency expert, says S.Ananthanaryanan.

Gregory S Engel, Graham Fleming and others at the University of California at Berkeley find that photosynthesis, which converts light energy into fuel and food with over 90% efficiency, follows quantum principles in working its magic.

Efficiency in motion

Soon after Newton's discovery of the laws of motion, there were others who noticed that the same laws arose from a concept of natural systems finding the most efficient way to get from one state to another.



Take the motion of a satellite. It moves around its sun in an oval, moving fastest when it is near the sun and very slowly when it is far away. It is when it is near the sun that it is accelerated the most.

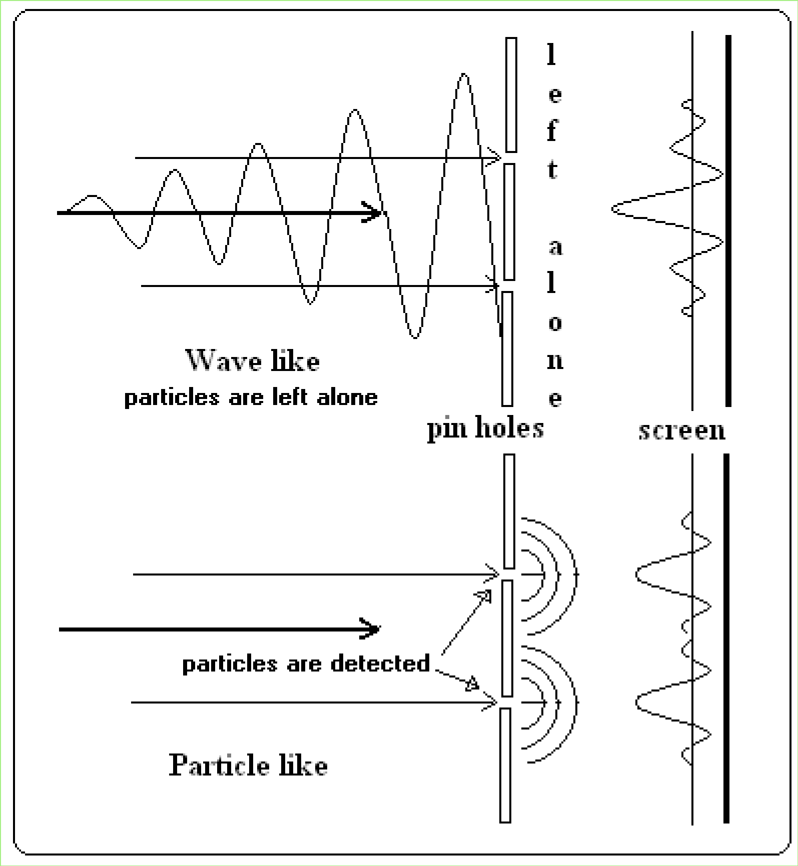
This makes for a lot of work getting done. But is also moving fast, which gets it all over quickly. When it is far, it is not accelerated that much and it is moving slowly. Hence, it lasts a long time and over a long distance and the same work, in the opposite sense, gets done anyway. But the way of nature is that use of energy at any time is 'parsimonious'.

This manner of time and energy combining for economy leads to an elegant way of stating the laws of physics, which has been a great aid to the developments of the last century, quantum mechanics and all that follows.

Quantum states

The other concept that has shaped physics is that systems left to themselves are not in a particular state of their variables, but in a combination of all possible states. In other words, things are at all places at once, only most likely to detected at some one set of nearby places. Another thing is that the states are not continuous, but separate, although close together. While things are thus in 'all states' when left alone, they 'fall into' one of the states, when disturbed, like when they are measured, some states being more likely than others.

This is noticeable only at the limit of smallness – at ordinary scales, the separate values are too close together to matter, and a small set of them are overwhelmingly likely to be detected at each measurement. We thus say that ordinary things are always 'in that state.'

But an atom-size particle passing through either of two microscopic holes, for instance, seems to pass through both holes at once, to yield a 'wave-like' interference pattern on a screen on the other side. But disturb the system, by detecting the particles at the holes and the pattern loses the wave character. It is these two concepts, of economy and wave nature, that have led to the development of lasers, atomic energy, transistors and almost all the marvels of recent times.	

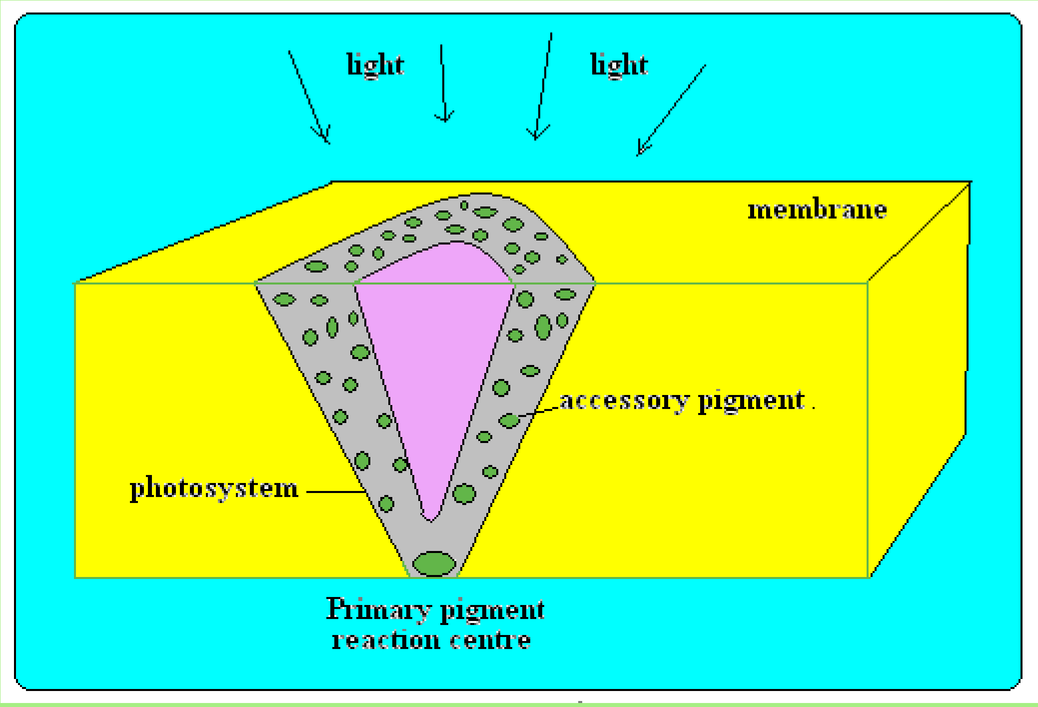
Quantum Computer

Being in many states at once leads to the idea of the new kind of computer. For most computer computations, the method is to try out all possible combinations of the values to see which set fits the circumstances. For example, finding which persons in a group have the same birthday would need comparing each person with every other person, to locate pairs. This may be daunting for a human, but a computer does it in a trice.

But when dealing with other problems, like weather forecasting, or breaking computer generated codes, even computers would take years, even centuries to resolve in a satisfactory way. It is in such cases that the idea of a system being in 'all states at once' becomes interesting. If we had a system of a good number of particles, which could each be in a number of states, and which had not been disturbed at all, the particles would be in 'all states at once'. The particles could represent the different factors in the problem, and the states their possible values. The 'coherent', ie undisturbed system would have all combinations 'at hand' and could find the solution at one go!

Photosynthesis

Plants and some bacteria convert light into chemical energy by capture of photons of light by a system of ‘antenna’ pigments in the plant. These then transfer excitation energy to a chlorophyll molecule at the core of the system. When sufficient energy is collected, an electron gets released, which sets into motion a process to create chemical units that can be stored as energy. The remarkable thing is that it all happens so efficiently, nearly all the energy is captured, very little used to warm up the plant or in ways that cannot be stored.



The Berkeley group measured how the photon signal reached the core of a photosynthetic antenna complex and found the signals seemed to bunch and ‘act together’, over sustained periods lasting hundreds of femtoseconds – a long time in the quantum world! The behaviour was characteristic of coherent coupling between the states of excited electrons. It looks like the different units act in unison, having used quantum computing to find the most efficient route, out of millions, to the core!

The experiments were done in laboratory conditions below -200º C. But the results may lead to efficient ways to harvest sunlight!